# NEW ESSENTIALS OF BIOLOGY

HUNTER

A Balanced Aquarium. The fish and other animals give off carbon dioxide and nitrogenous wastes which, under certain conditions, are used by the green plants for the manufacture of food and living matter. The plants give off oxygen as a by-product during starch making, and their bodies may be used as food by the animals.

# NEW ESSENTIALS OF BIOLOGY

## PRESENTED IN PROBLEMS


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## THE PLAN AND PURPOSE OF THIS BOOK

The plan of this book recognizes first-year biology as a *science* founded upon certain underlying and basic principles. These principles underlie not only biology, but also organized society. The culmination of such an elementary course is avowedly the understanding of man, and the principles which hold together such a course should be chiefly *physiological.* The functions of all living things, plants or animals, movement, irritability, nutrition, respiration, excretion, and reproduction; the interrelation of plants and animals and their economic relations, all these as they relate to man should enter into a course in elementary biology.

But to make plain these physiological processes, difficult even for an advanced student of biology to comprehend, the simplest method of demonstration is necessary. Plant physiology, because of the ease with which simple demonstrations can be made, is more profitable ground for beginners than is the physiology of animals. The foods which animals use are manufactured and used by green plants; the action of the digestive enzymes, the principle of osmosis, and the subject of reproduction can better be first handled from the botanical aspect. The topics just mentioned introduced from the standpoint of the botanist gain much by repetition from the zoölogical angle. The principles of physiology, after being applied in experiment to plants and animals, emerge in final clarity when applied at the last to man, — the most complex of all living things.

One sufficient reason for the placing of a course in biology in the first year of the secondary course lies in the fact that at this time the child is receptive to the message of applied biology. Private and public hygiene, the message of protective medicine and sanitation, the story of pure milk and of pure water and what they mean to a community; all these things can most logically be presented in a course that makes man the center. The allied topics of conservation of plant and animal life, the

destruction of harmful plants and animals, the relation of insects and other animals to the spread of disease, and the work of civic and government departments in the development of nature's gifts and in the preservation of national health should be treated in their relation to man.

Moreover, the data given should be treated from the *biological* standpoint, not that of botany, zoölogy, or human physiology. Ideally, we might take up general principles and draw from the great storehouses of plant, animal, and human biology to illustrate each principle before going on to the next. Practically, however, such a plan does not seem to be workable, partly because of the difficulty of collecting enough material to make such demonstrations possible. It is impracticable with immature students, because they cannot grasp the many-sidedness of the application at once. This will come only after *repetition* of the principle, each time from a slightly different point of view.

It frequently happens that the related study of plants and animals may be taken up to advantage. Insects and flowers, both plentiful in the fall, may well be studied together for the relation of life habits and adaptations in the insect to cross-pollination of flowers. Applied biology, in its relation to plants or to animals, must of course be treated from all sides. The fungi and the bacteria in their relations to man are conspicuous examples.

Teachers often spend too much time in teaching unessentials taken from an immense field, and do not spend enough time in emphasizing from constantly varied points of attack the *fundamental truths* on which the science of biology is built. The pages which follow are an attempt to drive home by repetition, and from many points of view, some of the important principles of physiological biology.

The plan of the book includes the solving of a number of problems in biology, each of which is more or less determined by the one immediately preceding it. So far as possible, the problems have a human interest. Abstractions are not part of the thought of a first-year pupil. Concrete problems, related when possible to the daily life of the pupil, have been used. The problems are stated in the form of laboratory exercises or suggestions, the material for which is in the hands of the pupil

or is worked out as a demonstration before the class. In all cases the laboratory types or physiological experiments demonstrate some important principle of biology.

The laboratory exercise immediately precedes the textbook discussion, the latter being used to clear up any false inferences the pupil may have made from the specimen in hand and to fix the object of the problem in the mind of the pupil. Too often has a laboratory exercise meant nothing to a pupil but "busy work." A plainly outlined and organized plan of attack, a few references to the text or tc previous work performed, and a definite problem will result in better and more definite laboratory work. For use with this book manuals for the solution of laboratory problems have been prepared by my coworker, Mr. R. W. Sharpe, and by myself. The latter manual, "Laboratory Problems in Civic Biology," gives an excellent point of attack through the interests of the student and gives a varied selection of problems for the teacher.

Two styles of type have been used in the text. The larger type contains material which is believed to be of first importance, the smaller type the less important topics. There are always some students whose grasp of subject matter or whose maturity places them above the average student. It is expected that the material in small type will be used to advantage with such students. Thus the material in small print will, to an extent, take the place of outside assigned reading and will, as well, give problem and project suggestions to those students whose interests are keenly biological.

The manuscript in its entirety was read by Professor H. E. Walter of Brown University, and by Miss A. P. Hazen, Head of the Department of Biology in the Eastern District High School; to them I owe sincere thanks for many helpful criticisms and suggestions. Acknowledgments are also due to H. G. Barber, E. A. Bedford, John E. McCarthy, and R. W. Sharpe of the DeWitt Clinton High School, and to Mr. C. W. Beebe, Curator of Birds, New York Zoölogical Park, for their careful reading and criticism of parts or all of the proof.

Thanks are due, also, to Professor E. B. Wilson, Mr. William C. Barbour, Dr. John A. Sampson, W. C. Stevens and C. W.

Beebe, Alvin Davison, and Dr. Frank Overton; to the United States Department of Agriculture; the New York Aquarium; the Charity Organization Society; the Folmer and Schwing Company, Rochester, N. Y.; and the American Museum of Natural History, for permission to copy and use certain photographs and cuts which have been found useful in teaching. R. W. Coryell and J. W. Tietz, two of my former pupils, made several of the photographs of experiments. Many of the line drawings in this revision are the work of Frank M. Wheat, whose scientific and artistic conceptions have added much to the value of the book.

At the end of each chapter is a list of books which have proved their use either as reference reading for students or as aids to the teacher. Most of the books mentioned are within the means of the small school. Two sets are expensive: one, *The Natural History of Plants*, by Kerner, translated by Oliver, published by Henry Holt and Company, in two volumes; the other, *Plant Geography upon a Physiological Basis*, by Schimper, published by the Clarendon Press; but both works are invaluable for reference.

For a general introduction to physiological biology, the following are most useful and inspiring books: Parker, *Lessons in Elementary Biology*, The Macmillan Company; Sedgwick and Wilson, *General Biology*, Henry Holt and Company; Shull, *Principles of Animal Biology*, McGraw-Hill Company.

Three books stand out from the pedagogical standpoint as by far the most helpful of their kind on the market. No teacher of botany or zoölogy can afford to be without them. They are: Lloyd and Bigelow, *The Teaching of Biology*, Longmans, Green, and Company; C. F. Hodge, *Nature Study and Life*, Ginn and Company; and Twiss, *Principles of Science Teaching*, The Macmillan Company. The last-named book gives the modern pedagogical interpretation of the introductory sciences. Other books of value from the teacher's standpoint are: Ganong, *The Teaching Botanist*, The Macmillan Company; L. H. Bailey, *The Nature Study Idea*, Doubleday, Page and Company; and McMurry's *How to Study*, Houghton Mifflin Company.

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# NEW ESSENTIALS OF BIOLOGY

## I. SOME REASONS FOR THE STUDY OF BIOLOGY

**What is Biology?** — *Biology is the study of living beings, both plant and animal.* Inasmuch as man is an animal, the study of biology includes the study of man in his relation to the plants and the animals which surround him. Most important of all is that branch of biology which treats of the mechanism we call the human body, — of its parts and their uses, and its repair. This subject we call *human physiology.*

**Why study Biology?** — Although biology is a very modern science, it has found its way into most high schools; and an increasingly large number of boys and girls are engaged in its study. The question might well be asked by any of these students, Why do I take up the study of biology? Of what practical value is it to me? Aside from the discipline it gives me, is there anything that I can get from it which will help me in my future life as a boy or girl with only a high school education?

**Human Physiology.** — The answer to this question is plain. If the study of biology will give us a better understanding of our own bodies and their care, then it certainly is of use to us. That phase of biology known as *physiology* deals with the uses of the parts of a plant or animal; human physiology deals with the uses, and *hygiene* (hī′jĭ-ēn) with the care, of the parts of the human animal. Much sickness may be prevented by living according to the laws which hygiene teaches. It is estimated that 400,000 out of the 1,600,000 deaths that occur yearly in this country could be averted if only every one lived in a hygienic (hī-jĭ-ĕn′ĭk) manner. In its application to the life of each of us, as a member of a family, as a member of the school we attend, and as a future citizen, a knowledge of hygiene is of the greatest importance.

**Relations of Plants to Animals.** — But there are other reasons why an educated person should know something about biology. We do not always realize that if it were not for the green plants, there would be no animals on the earth. Green plants furnish animals with their food. Even the meat-eating animals feed in the long run upon those that feed upon plants. How the plants manufacture this food and the relation they have to animals will be discussed in later chapters. Plants furnish man with the greater part of his food in the form of grains and cereals, fruits and nuts, edible roots and leaves; they provide his domesticated animals with food; they give him timber for his houses and wood and coal for his fires; they provide him with pulp wood, from which he makes his paper, and oak galls, from which he obtains ink. Much of man's clothing and the thread with which it is sewed come from fiber-producing plants. Most medicines, beverages, flavoring extracts, and spices are plant products, while plants are made use of in hundreds of ways in the useful arts and trades, producing varnishes, dyestuffs, rubber, and other products.

Banana plants. Each plant bears one bunch of bananas and is then cut down. New plants grow up from the root.

**Bacteria in their Relation to Man.** — In still another way, certain tiny plants vitally affect mankind. These plants, so small that millions can exist in a single drop of fluid, are called *bacte'ria*

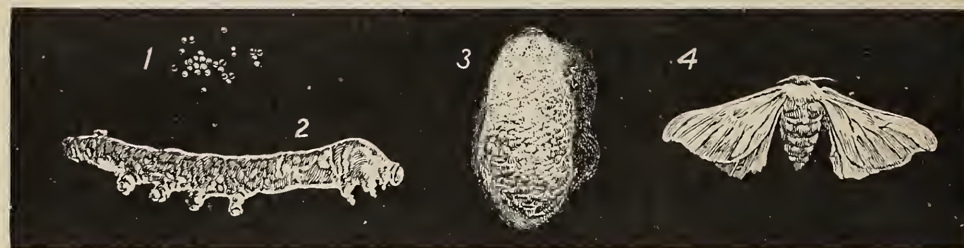
or *germs*. Existing almost everywhere about us, — in water, soil, food, and the air, — they play a tremendous part in shaping the destiny of man on the earth. They help him in that they act as scavengers, causing things to decay; they give flavor to cheese and butter; they assist the tanner, and are invaluable to the farmer; but they likewise cause decay of our meat and fish, and our vegetables and fruits; they sour our milk, and spoil our canned goods. More than this, they cause diseases, among others tuberculo′sis, a disease so harmful as to be called the " white plague." Fully one half of the deaths each year are caused by these plants. So important are bacteria that a subdivision of biology, called *bacteriol′ogy*, has been named after them, and hundreds of scientists are devoting their lives to the study of germs and their control. The greatest of all bacteriologists, Louis Pasteur (pȧs-tûr′),[1] once said, " It is within the power of man to cause all parasitic diseases [diseases caused mostly by bacteria] to disappear from the world." His prophecy is gradually being fulfilled, and it may be the lot of some boys or girls who read this book to do their share in helping to bring about this condition of affairs.

**Harmful Relation of Animals to Man.** — Animals play an important part in the world in causing and carrying disease. Animals that cause disease are usually tiny, and live upon other animals as parasites; that is, they get their living from their hosts on which they feed. Among the diseases caused by parasitic animals are malaria, yellow fever, sleeping sickness, and hookworm disease. Animals also *carry* disease, especially the flies and mosquitoes; rats and other animals are well known also as spreaders of disease. From a money standpoint, insects do much harm. It is estimated that in this country alone in 1922 they were responsible for over $2,000,000,000 worth of damage to crops, stored foods, and forest products.

**The Uses of Animals to Man.** — We all know the uses man has made of domesticated animals for food and as beasts of burden. But many other uses are found for animal products, and materials made from animals. Wool, furs, leather, hides, and feathers are examples. The arts make use of ivory, tortoise

[1] The diacritic marks are those used in the Webster school dictionaries.

shell, coral, and mother of pearl; from animals also come certain perfumes and oils, glue, lard, and butter; animals produce honey, wax, milk, eggs, silk, and various other commodities.




The silkworm: 1, eggs; 2, larva or silkworm; 3, cocoon spun by the larva; 4, the adult moth, which comes from the cocoon and lays the eggs from which new larvæ are hatched. The cocoons are made of silk threads, which can be unwound.

**The Conservation of our Natural Resources.** — Still another reason why we should study biology is that we may work intelligently for the conservation of our natural resources, especially our forests. The forest, aside from its beauty and its health-giving properties, holds water in the earth. It keeps the water from drying out of the earth on hot days and from running off on rainy days. Thus a more even supply of water is given to our rivers, and freshets are prevented. Countries that have been deforested, such as parts of China, Italy, and France, are now subject to floods, and are in many places barren. On the forests depend our supply of timber and to a large extent our future water power.

Raising silkworms in Japan. The silkworms are fed on mulberry leaves and must be carefully tended.

**Plants and Animals mutually Helpful.** — The study of biology also shows us the interrelation existing between plants and ani-

mals on the earth. Most plants and animals stand in an attitude of mutual helpfulness: plants providing food and shelter for animals; animals giving off waste materials useful to plants in the making of food. We learn also that plants and animals need the same conditions in their surroundings in order to live: water, air, food, a favorable temperature, and usually light. We learn that the life processes of both plants and animals are essentially the same, and that the living matter of a tree is as much alive as is the living matter in a fish, a dog, or a man.

**Biology in its Relation to Society.** — Finally, the study of biology should be part of the education of every boy and girl, because society itself is founded upon the principles which biology teaches. Plants and animals are living things, each taking what it can from its surroundings; they enter into competition with one another, and those which are the best fitted for life outstrip the others. Health and strength of body and mind are factors in man which tell in winning. The strong may hand down to their offspring the characteristics which make them the winners.

Man has made use of this message of nature, and has developed improved breeds of horses, cattle, and other domestic animals. Plant breeders have likewise selected plants and seeds with great care and thus have stocked the earth with hardier and more fruitful domesticated plants. Man's dominion over the living things of the earth is tremendous. It is due to the understanding of the principles which underlie the science of biology.

**Problem Questions.** — 1. Why should biology be studied by all girls and boys of high school age?

2. Of what use to the average citizen is a knowledge of biology?

## II. THE ENVIRONMENT OF LIVING THINGS

**Environment.** — Living plants and animals are surrounded by various substances and forces. Air, light, water, the presence or absence of food, changing conditions of temperature, even such a force as electricity, may influence the growth or behavior of any living thing. Plants and animals take some outside substances into their bodies and are externally influenced by others. The total of all the surrounding forces which act upon living things helps to form their *envi'ronment.* We shall later see that the environment may cause great changes to take place in the structure or habits of a plant or animal. It is the purpose of this chapter to try to explain something of how plants and animals are influenced by the factors of their environment.

In order to understand better what a living plant or animal takes from its environment, we must find out something about the air, water, and the soil, for it is with these factors that the plant and the animal are in immediate contact.

**Problem.** *How to learn the part played by the common elements in the environment of living things.* (*Laboratory Manual,*[1] *Prob. I; Laboratory Problems,*[2] *Probs. 37, 38, 39, 40.*)

(*a*) *Nitrogen.*

(*b*) *Oxygen and oxidation.*

(*c*) *Hydrogen.*

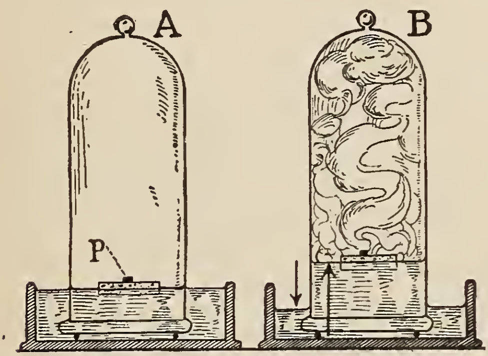
(*d*) *Carbon and carbon dioxide.*

**The Composition of the Air.** — If we invert a large bell jar over a deep tray containing water, having previously placed a float holding a bit of burning phosphorus (fŏs'for-us) upon the surface of the water, we find that, as the phosphorus burns, the water

[1] Sharpe, *A Laboratory Manual for the Solution of Problems in Biology,* American Book Company.

[2] Hunter, *Laboratory Problems in Civic Biology,* American Book Company.

slowly rises in the jar. After a little the fire goes out. The water now displaces a volume equal to about one fifth of the space occupied by the air in the jar. When the water reaches this height, it goes no higher, and, no matter how many times or how carefully the experiment is repeated, the phosphorus always stops burning when the water displaces one fifth of the air in the jar.



Experiment to show the amount of oxygen in the air. *A* before, and *B* after the phosphorus *p* is lighted.

Evidently, the burning of the phosphorus uses up some gas within the jar which supports the flame, and the gas which remains in the jar, occupying about four fifths of the space, does not have the power to maintain the flame. The former gas is *oxygen* (ŏx′ĭ-jĕn); nearly all the latter is *ni′trogen.* These two gases form the principal constituents of the air in nearly the proportion seen in the experiment. The white gas formed by the combination of the oxygen with the phosphorus is absorbed by the water in the tray.

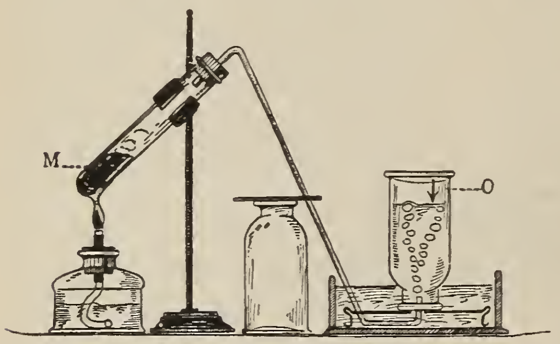
**Chemical Elements.** — All the materials of this universe, both living and lifeless, are classified by chemists as either *chemical elements* or *chemical compounds.* A *chemical element* is a substance which chemists have not been able to break up or decompose into simpler substances. Examples of elements are *oxygen,* making up about 20 per cent of the atmosphere; *nitrogen,* composing nearly all the remainder of pure air; *carbon,* an element that enters into the composition of all organic matter; and over seventy others of more or less importance to us in the study of biology.

**Nitrogen.** — The physical properties (those which we determine through our senses) of nitrogen are its lack of color, taste, and odor. Its chief chemical characteristics are its inability to support combustion and its slight tendency to combine with other substances. We shall later find that nitrogen is one of the most important chemical elements found in living matter. In spite of this, animals

and *most* plants are absolutely unable to take any nitrogen from the air, no matter how much they may need it.

The other principal element in the air, oxygen, is taken out by plants and animals. We shall be able to see how, after studying the properties of oxygen.

**Preparation of Oxygen. Elements and Compounds.** — Oxygen may be prepared by heating half a teaspoonful of chlorate of potash with a little less than its bulk of black oxide of manganese in a test tube over a flame. The chlorate of potash and oxide of manganese are made up of chemical elements which have united to form chemical compounds. A combination of two or more elements according to certain laws is called a compound. In the mixture of the compounds named above heat will free the oxygen, as is proved by a glowing match end bursting into flame when held over the mouth of the test tube, or by testing the gas collected in a bottle as shown in the Figure. We have decomposed the two chemical compounds and in the process we have released the element oxygen. This is an example of a *chemical change.*




The mixture of chemicals in the test tube $M$ is decomposed by heat and gives off the gas oxygen $O$, which is collected by displacing water.

**Properties of Oxygen.** — Oxygen, when carefully prepared, is found to be colorless, odorless, and tasteless. Combined with other substances, it forms a very large part by weight of water rocks, minerals, and the bodies of plants and animals.

Oxygen has the very important property of *uniting* with many other substances. *The chemical union of oxygen with another substance is called oxidation.* Rapid oxidation produces a flame or light. Oxidation, either rapid or slow, may take place wherever oxygen is present. This fact has a far-reaching significance in the understanding of the most important problems of biology.

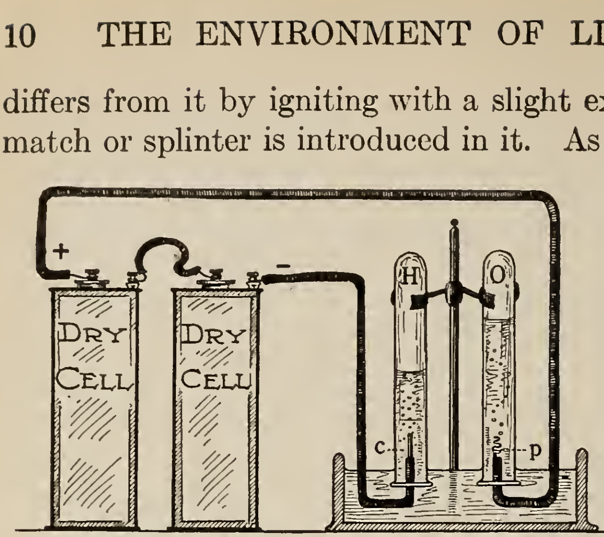
**Oxidation in a Match.** — The simple process of striking a sulphur match gives us an illustration of this process of oxidation. The head of the match is formed of a combination of phosphorus, sulphur, and some other materials. Phosphorus is a chemical element distinguished by its extreme inflammability; that is, it unites with oxygen at a comparatively low temperature, producing a flame. Sulphur is another chemical element that combines somewhat easily with oxygen but at a much higher temperature. The rest of the match head is made up of red lead, niter, or some other substance that will release oxygen, and some glue or gum to bind the materials together. The heat caused by the friction of the match head against the striking surface is enough to cause the phosphorus to ignite; this in turn ignites the sulphur; and finally the wood of the match, composed largely of the element carbon, is lighted and oxidized. If we could take out the different chemical elements of which the match is formed and oxidize them separately, we should find that the amount of heat needed to start the oxidation of the substances would vary greatly.

**Slow Oxidation.** — Oxidation may take place slowly, as seen in the rusting of an iron nail. If the rust and nail are weighed, the total weight will be more than the original nail. Do you see why? Rust is iron oxide, and is formed by the union of iron and oxygen. Slow oxidation of chemical compounds is constantly taking place in nature and is a part of the process of decay and of breaking down of complex materials into simpler forms.

**Heat given off as Result of Oxidation.** — One of the most important effects of oxidation lies in the fact that, when anything is oxidized, heat is produced. This heat may be of the greatest use. Coal, in being oxidized, gives off heat; this heat boils the water in the tubes of a boiler; steam is generated, wheels of an engine are turned, and work is performed. The energy released by the burning of coal may be transformed into any kind of work power. *Energy is the ability to perform work.* We shall find later that the oxidation of certain materials in the bodies of plants or animals releases energy. The heat of the human body is maintained by constant slow oxidation of food materials within the body.

**The Composition of Water.** — If an electric current is passed through water by means of the apparatus shown in the Figure on the next page, the water separates into two gases, one of which occupies twice as much space as the other in the tubes. If we test the gas present in smaller quantity, we find it to be oxygen. The other gas, colorless, tasteless, and odorless like the oxygen,

differs from it by igniting with a slight explosion when a burning match or splinter is introduced in it. As it burns, drops of water are formed, showing that it is passing back to its original condition, that is, it is uniting with oxygen to form water. This gas is *hydrogen* (hī'dro-jĕn). Hydrogen has a great chemical affinity or liking for other elements, hence it is usually found in nature combined with other elements, as with oxygen in water.



Apparatus for separating water into hydrogen *H* and oxygen *O*: *c*, copper wire; *p*, platinum wire soldered to the copper, with insulation so that no copper is exposed in this tube. A few drops of sulphuric acid should be added to the water, to facilitate the action of the electric current.

**The Composition of the Soil.** — The covering of the earth was probably very different in former ages from what it is now. Its molten plastic mass after cooling formed rock. This rock, by the work of the wind, frost, heat, water, and plants, has in part been broken into small bits. This is inorganic soil, as sea sand and gravel, formed usually of several elements found in rocks, such as cal'cium, sodium, magne'sium, sil'icon, potas'sium, and iron, all combined with oxygen.

A visit to the woods or to a well-kept garden shows us that there is another kind of soil than the inorganic soil just mentioned. This is the rich, dark soil containing *hu'mus*. Humus is made up largely of dead organic matter, the decayed remains of plants and animals. If we could test the chemical elements to be found in humus, we should find nitrogen, hydrogen, oxygen, and also carbon, an important element found in all organic matter.

**Carbon.** — Carbon is found in many conditions in nature. It is found in the bodies of plants and animals, and in coal (fossil plants), and it exists in a nearly pure state in the diamond. The presence of carbon can usually be detected by partly burning or *charring* a substance; the carbon, if present, remains as a black substance without taste or odor. Carbon may be collected by

allowing a candle flame to burn in contact with the under side of a sheet of glass. The black deposit is almost pure carbon.

**Oxidation of Carbon and its Result.** — If we burn a candle in a closed jar containing air, the flame soon begins to flicker, and then goes out. If the cover of the jar is *carefully* removed, and a burning match lowered into the jar, the match will at once go out, showing the presence of a gas heavier than air which will not support a flame. Nitrogen of course is present, but we shall make a test for another gas, — a test to which nitrogen will not respond. If we pour into the jar a few spoonfuls of limewater,[1] a colorless liquid, and shake it up with the gas in the jar, the limewater turns milky in color. This is a test for a compound known as *carbon dioxide,* which was evidently formed by the union of the carbon of the candle with the oxygen of the air in the jar.

All organic or living substances, when oxidized, form carbon dioxide besides giving off water vapor. That oxidation of carbon takes place within our own bodies may easily be proved by exhaling through a clean glass tube into some limewater; and that water vapor is given off, by breathing against a clean, dry glass. The heat of the human body (98.6° F.) is the result of oxidation taking place within the body. The heat given off from oxidation of wood or coal in a stove is determined by the supply of oxygen we allow to pass to the burning material. If we open the draft, allowing more oxygen to get to the fire, we increase the heat by more rapid oxidation; if we shut off the oxygen supply, we decrease the amount of oxidation.

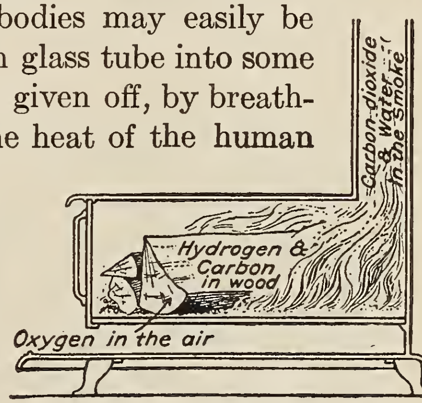


Diagram of combustion or rapid oxidation in a stove.

***Problem.*** *Are mineral matter and water present in living things? (Laboratory Manual, Prob. II; Laboratory Problems, Probs. 30, 31.)*[2]

[1] Limewater can be made by shaking up a piece of quicklime the size of your fist in about two quarts of water. Filter or strain the limewater into bottles, and it is ready for use.

[2] See notes on page 6.

(*a*) *Mineral matter.*
(*b*) *Water.*

**Mineral Matter in Living Things.** — If a piece of wood is burned in a very hot fire, the carbon in it will all be consumed, and eventually nothing will be left except a grayish ash. This ash is seen after a wood fire in the fireplace, or after a bonfire of dry leaves. It consists of mineral matter which the plant has taken up from the soil dissolved in water, and which has been stored in the wood or leaves. All living things contain small quantities of mineral substances.

**Water in Living Things.** — Water forms an important part of the substance of plants and animals. This is easily seen by weighing a number of green leaves, placing them in a hot oven for a few moments, and then reweighing. The same experiment made with a soft-bodied animal, as the oyster, would show the presence of even more water than in leaves. Some jellyfish are over 90 per cent water. About 65 per cent of the human body is water.

**Gases Present.** — Some gases are found in a free state in the bodies of plants or animals. Oxygen is of course present wherever oxidation is taking place, as is carbon dioxide. Other gases may be present in minute quantities.

***Problem.*** *What foods do living organisms need?* (*Laboratory Manual, Prob. III; Laboratory Problems, Probs. 26, 27, 28, 29.*)

**Composition of Living Matter.** — The living part of a plant or animal is made up of the elements carbon, hydrogen, oxygen, and nitrogen, with a very minute amount of several other elements, which collectively we may call mineral matter. The living part of a plant corresponds closely in chemical composition to the living part of an animal. The starch found in grains or roots of plants has nearly the same chemical formula as the animal starch found in the liver of man; the oils of nuts or fruits are of a composition closely allied to the fat in the body of an animal. These and other building materials of a plant or animal may be placed in the three following groups of substances: *carbohydrates* (car-bo-hī′drāts), materials containing a certain proportion of carbon, hydrogen, and oxygen; *fats* and *oils*, which contain chiefly hydrogen and

carbon with less oxygen; and *nitrogenous* (nī-trŏj′e-nus) substances, or *proteins* (prō′tē-ĭnz), which contain nitrogen in addition to the above-mentioned elements. The above three kinds of organic materials also form a large part of the foods of all animals and plants.

**Foods.** — *What is a food?* We know that if we eat a suitable amount of proper foods at regular times, we shall be able to go on doing a certain amount of work, both manual and mental. We know, too, that day by day, if our general health is good, we may be adding weight to our bodies, and that added weight comes as the result of taking food into the body. A similar statement may be made with reference to plants and foods. If food is supplied in proper quantity and proportion, plants will live and grow; if the food supply is cut off, or even greatly reduced, they will suffer and may die. From this, the definition which follows is evident. *Food is any material which repairs or builds up the body of a plant or animal, or, when oxidized in the body, furnishes it with energy.*

**Nutrients.** — Organic food substances are called *nu′trients;* they may be classed into a number of groups, each of which may be detected by means of a chemical test. Such groups of nutrients are carbohydrates, fats and oils, and proteins.

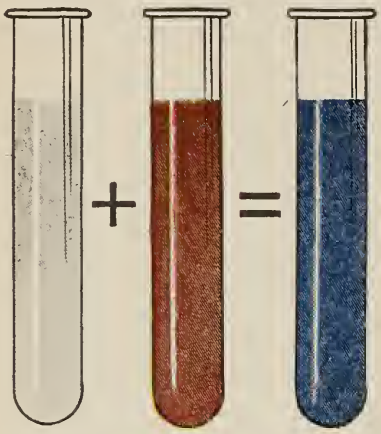
**Carbohydrates.** — Starch and sugar are common examples of this group of substances. The former we find in our cereals, bread, cake, and most of our vegetables. Several kinds of sugar are commonly used as food; for example, cane sugar, beet sugar, and glucose or grape sugar. Glucose, found as the natural sugar of grapes, honey, and fruits, is manufactured commercially by pouring sulphuric acid over starch. It is used as an adulterant for many kinds of foods, especially in sirups, honey, and candy.

**Test for Starch.** — If we shake up a piece of laundry starch in water, in a test tube, and then add to the mixture two or three drops of iodine solution,[1] we find that the particles of starch in the test tube turn purple or deep blue. It has been discovered by experiment that starch, and *no other known substance*, will be

[1] Iodine solution is made by simply adding a few crystals of the element iodine to 95 per cent alcohol; or, better, take by weight 1 gram of iodine crystals, $\frac{2}{3}$ gram of iodide of potassium, and dilute to a dark brown color in weak alcohol (35 per cent) or distilled water.

turned purple or dark blue by iodine. Therefore, this has come to be used as a test for the presence of starch.

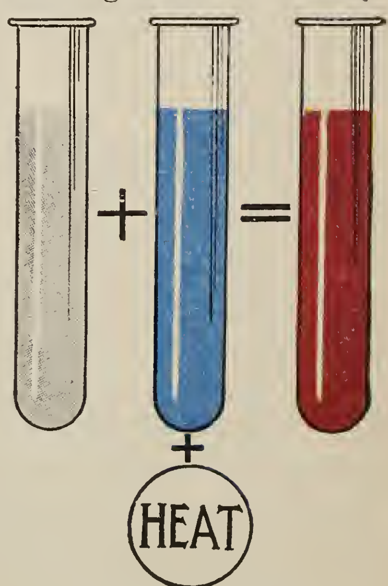
**Test for Grape Sugar.** — Place in a test tube the substance to be tested and heat it in a little water so as to dissolve the sugar. Add to the fluid twice its bulk of Fehling's solution[1] which has been previously prepared. The mixture should now have a blue color, in the test tube. When heated, if grape sugar is present in considerable quantity, the contents of the tube will turn first a greenish, then a yellow, and finally a brick-red color. Smaller amounts will show less decided red. No other substance than grape sugar will give this reaction.



Test for starch.

**Fats and Oils.** — Fats and oils form an important part of the composition of plants and animals. Examples of food in the form of fat are butter and cream, the oils from nuts, olives, and other fruits, and fat from animals.

**Test for Fats and Oils.** — The characteristic "grease spot" is an easy way of determining if a substance has fat or oil in it. If the substance is a fluid, pour a little of it on white paper; or if it is a solid, rub it a few times on the paper. Then hold the paper to the light. A translucent spot indicates the presence of fat or oil. A more scientific test is to mash the substance to be tested, place it in an evapo-




Test for grape sugar.

[1] To make Fehling's solution (so-called after its discoverer), add to 35 grams of copper sulphate (blue vitriol) 500 c.c. of water. Put aside until it is completely dissolved. Call this solution No. 1.

To 160 grams of caustic soda and 173 grams of Rochelle salt add 500 c.c. of water. Call this solution No. 2.

For use mix equal parts of solutions 1 and 2.

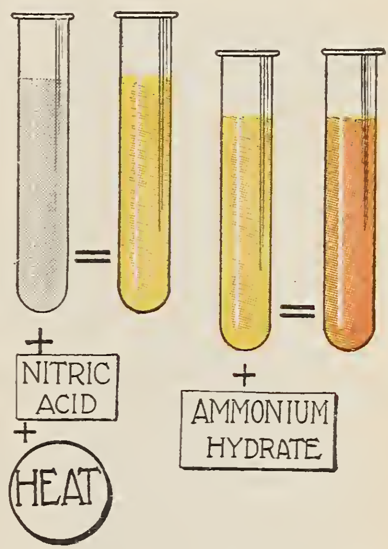
rating dish, and then pour ether over it. If fat is present the ether will dissolve it and upon evaporation of the ether the fat will remain in the dish.

**Proteins.** — Nitrogenous foods, or proteins, contain the element nitrogen in addition to carbon, hydrogen, and oxygen of the carbohydrates and fats and oils. They include some of the most complex substances known to the chemist, and, as we shall see, have a chemical composition very near to that of living matter. Proteins occur in many different substances. White of egg, lean meat, beans, and peas are examples of substances composed largely of proteins.

**Tests for Proteins.** — Place in a test tube the substance to be tested; for example, a bit of hard-boiled egg. Pour over it a little strong (80 per cent) nitric acid. Note the color that appears — a lemon yellow. If the egg is washed in water and a little ammonium hydrate added, the color changes to a deep orange. This shows that a protein is present.

If the substance is in a liquid state, the presence of protein may sometimes be proved by heating, for when it coagulates or thickens, as does the white of an egg when boiled, protein in the form of an *albu'men* is present.

Another characteristic protein test easily made at home is burning the substance thought to contain it. If the odor of burning feathers or leather is given off, then protein forms part of its composition.



Test for protein.

Proteins occur in several different forms, but the preceding tests will cover the cases most commonly met.

**Inorganic Foods.** — Water and various salts, some of which, as lime, may be found in drinking water, form important parts in the diet of plants and animals. Later we shall see that green plants, although they use precisely the same foods (carbohydrates, oils, and proteins) as we do, take into their bodies the chemical elements from which these are formed. From these *raw* food

materials, organic foods are manufactured in the body of the plant.

**Summary.** — This chapter has shown us that the factors of the environment for both plants and animals are the same. Both use the chemical elements in air, water, and food in building their bodies or in releasing energy through oxidation of food materials. Both plants and animals are affected by the forces of nature which form part of their natural environment. It will be the work of future chapters to explain how.

**Problem Questions.** — 1. What is the physical environment of a living thing?

2. What is an element? a compound? How is a compound formed?

3. Distinguish between rapid and slow oxidation. For what purposes is food used by plants and animals?

4. What are nutrients? Explain.

5. What is the general purpose of this chapter?

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# III. THE FUNCTIONS AND COMPOSITION OF LIVING THINGS

**Problem.** *An introduction to the nature and work of living organisms. (Laboratory Manual, Prob. IV; Laboratory Problems, Probs. 1, 17, 18.)*

(*a*) *A living plant.*

(*b*) *A living insect.*

**A Living Plant and a Living Animal Compared.** — A walk into the fields or a vacant lot on a day in the early fall will give us first-hand acquaintance with many common plants which, because of their ability to grow under unfavorable conditions, are called *weeds*. Such plants — the dandelion, butter and eggs, the shepherd's purse — are particularly well fitted by nature to produce many of their kind and by this means drive out other plants which do not multiply so fast. On these and other plants we find feeding several kinds of animals, chiefly insects.

A weed. Notice that the soil is barren, yet the weed flourishes. Photograph by W. A. Barbour.

If we attempt to compare, for example, a grasshopper with the plant on which it feeds, we see several points of likeness and difference at once. Both plant and insect are made up of parts, each of which, as the stem of the plant or the leg of the insect, appears to be distinct, but which is a part of the whole living plant or animal. Each part of the living plant or animal which has a separate work to do is called an *organ*. Plants and animals are spoken of as *or'ganisms* because they are made of organs.

**Functions of the Parts of a Plant.** — We are all familiar with the parts of a plant, — the root, stem, leaves, flowers, and fruit

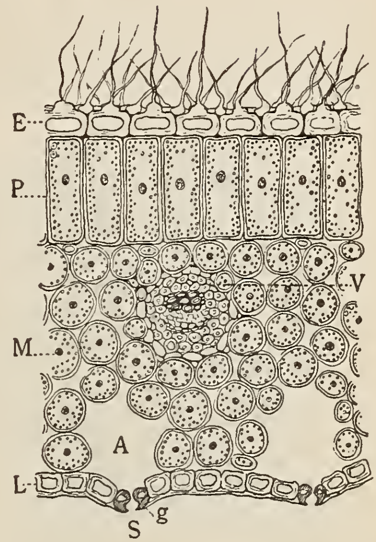
But we may not know so much about their uses to the plant. Each of these structures differs from every other part, and each has a separate work or function to perform for the plant. *The root holds the plant firmly in the ground and takes in water and mineral matter from the soil; the stem holds the leaves up to the light and acts as a pathway for fluids between the root and leaves; the leaves, under certain conditions, manufacture food for the plant and breathe; the flowers form the fruits; the fruits hold the seeds, which in turn hold young plants which are capable of reproducing adult plants of the same kind.*

**The Functions of an Animal.** — If we examine the grasshopper more carefully, we find that it has a head, a jointed body composed of a middle and a hind part, three pairs of jointed legs, and two pairs of wings. Obviously, the wings and legs are used for locomotion; a careful watching of the hind part of the animal shows us that breathing movements are taking place; a bit of grass placed before it may be eaten, the tiny black jaws biting little pieces out of the grass. If disturbed, the insect hops away, and if we try to get it, it jumps or flies away, evidently seeing us before we can grasp it. Hundreds of little grasshoppers indicate that the grasshopper can reproduce its own kind, but in other respects the animal seems quite unlike the plant. The animal moves, breathes, feeds, and has sensation, while *apparently* the plant does none of these. It will be the purpose of later chapters to prove that the functions of plants and animals are in many respects similar and that both plants and animals breathe, feed, and reproduce.

**Organs.** — If we look carefully at the organ of a plant called a leaf, we find that the materials of which it is composed do not appear to be everywhere the same. The leaf is much thinner and more delicate in some parts than in others. Holding the flat, expanded blade away from the branch is a little stalk, the *pet'iole*, which extends into the blade of the leaf. Here it splits up into a network of tiny veins which evidently form a framework for the flat blade somewhat as the sticks of a kite hold the paper in place. If we examine under the compound microscope a thin section cut across the leaf, we shall find that the veins as well as the other parts are made up of many tiny boxlike units.

These smallest units of building material of the plant or animal disclosed by the compound microscope are called *cells*. All the organs of a plant or animal are built of these minute structures, which are of various sizes and shapes.

**Tissues.** — The cells which form certain parts of the veins, the flat blade, or other portions of the plant, are often found in groups or collections, in which the cells are more or less alike in size and shape. A collection of similar cells is called a *tissue*. Examples of tissues are the cells covering the outside of the human body, the muscle cells, which collectively allow of movement, bony tissues which form the framework to which the muscles are attached, and many others.

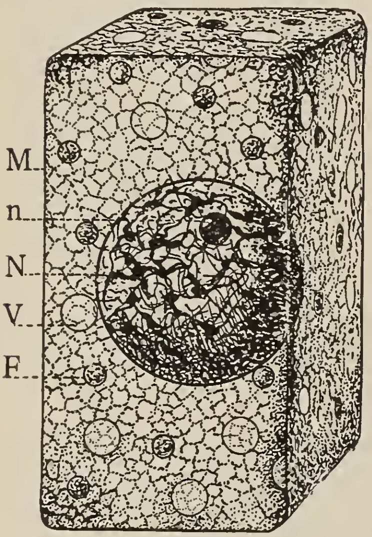



Section through a leaf, greatly magnified: *E*, cells of upper epidermis; *P*, palisade layer; *V*, vein; *M*, cells with air spaces, *A*, between them; *L*, cells of lower epidermis; *S*, stoma or mouth-like opening; *g*, guard cell.

**Adaptations of Structure to Function.** — If I look at my hand as I write, I notice that the fingers of my right hand grasp the pen firmly; that because of the several joints in the fingers, the wrist, and forearm, free movement can be given to the hand when the muscles attached to the bones move it. The hand is capable of a great number of complicated and delicate movements, most of them associated with the work of grasping objects. Because of the peculiar fitness in the structure of the hand for this work, we say that it is *adapted* to this function, that is, grasping objects. Each organ of the plant is fitted or adapted in some way to do certain kinds of work. It is the object of the chapters following to point out how the parts of a plant or animal are adapted to their various functions.

**Problem.** *To discover the structure and properties of living matter.* (*Laboratory Manual, Prob. V; Laboratory Problems, Prob. 19.*)

**Cells.** — Living things, when viewed under a compound microscope, are found to be made up of tiny units of structure, or cells, each separated from its neighbors by a very delicate membrane or a wall. The inside of the cell is composed of grayish semifluid matter which seems to contain innumerable granules of various sizes and shapes. This substance is known as *protoplasm* (prō′tō-plăzm), and usually contains a structure known as the *nucleus* (nū′klē-ŭs). Within the nucleus are tiny bits of matter which, when the cell is stained with logwood or other dyes, take up the stain more readily than the surrounding material and hence are called *chromosomes* (krō′mō-sōmz), which means "color-bearing bodies." A distinction is usually made between the protoplasm within the nucleus and that within the rest of the cell body, the latter being called *cytoplasm* (sī′tō-plăzm). A *cell* may be defined as *a unit of structure in all living things, a tiny mass of living matter usually containing a nucleus.*



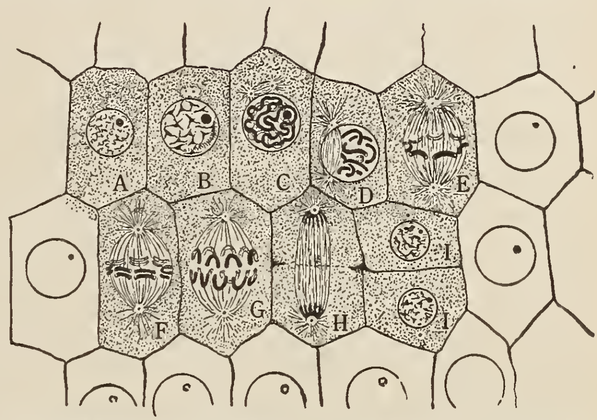

A typical cell, composed of protoplasm. The cell may be of almost any shape. *M*, cell wall or cell membrane; N, nucleus; *n*, nucleolus; *V*, vacuole; F, food or other substance.

The cell is surrounded by a very delicate living structure called the *cell membrane.* Outside this membrane a wall is formed by the activity of the protoplasm in the cell. These cell walls, in plants, are of *cel′lulose* or *wood.*

**How Cells form Others.** — A cell grows to a certain size and then splits into two new cells. In this process, which is of very great importance in the growth of both plants and animals, the chromosomes divide first. Each chromosome splits lengthwise and the parts go in equal numbers to each of two nuclei formed from the old nucleus. The chromosomes are believed to be the bearers of the qualities which can be handed down from plant to plant and from animal to animal; in other words, the inheritable qualities which make the offspring like its parents. Lastly, a cell wall is developed dividing the cytoplasm, and two

new cells are formed. This process is known as *cell division.* It is the usual method of growth found in the tissues of plants and animals.

**Cells of Various Sizes and Shapes.** — Plant cells and animal cells are of very diverse shapes and sizes. There are cells so large that they can easily be seen with the unaided eye; for example, the root hairs of plants and eggs of some animals. On the other hand, cells may be so minute that, as in the case of the plant cells named bacteria, a million could be placed within this letter *o*. The forms of cells may be extremely varied in different tissues; they may assume the form of cubes, columns, spheres, flat plates, or may be extremely irregular in shape. One kind of tissue cell has a body so small as to be quite invisible to the naked eye, although it has a prolongation several feet in length. Such are some of the cells of the nervous system of man and other large animals, as the ox, elephant, and whale.



Stages in the division of one cell to form two cells. Note the separation of the chromosomes in the nucleus. Which part of the cell divides first?

**Varying Sizes of Living Things.** — Plant cells and animal cells may live alone or they may form collections of cells. Some plants are so simple in structure as to be formed of only one kind of cells. Usually living organisms are composed of several groups of different kinds of cells. The size of the cells does not seem to bear any relation to the size of the organism, but larger organisms are made up of more cells. The human body, for example, is composed of untold millions of cells, while some simple plant or animal may be composed of a very few cells or even a single cell.

**Relation to Organic and Inorganic Matter.** — The cells of which we have been speaking are examples of organic matter. They live and grow and in doing so make use of the inorganic

matter covering the earth, as air, water, and soil. Plants and animals make their homes in earth, air, or water; they take in the oxygen of the atmosphere; they take in water; but in the main the food of animals consists of organic matter. Green plants, on the other hand, manufacture most of their food out of the inorganic matter contained in the soil, air, and water, and then change this food into the living matter of their own bodies. This organic matter in turn may become food for animals.

**Chemical Composition of Protoplasm.** — Living matter, when analyzed by chemists in the laboratory, seems to have a very complex chemical composition. It is somewhat like a protein in that it always contains the element nitrogen. It also contains the elements carbon, hydrogen, oxygen, and a little sulphur. Calcium, iron, silicon, sodium, potassium, phosphorus, and other mineral matters are usually found in very minute quantities in its composition. We believe that the matter out of which plants and animals are formed, although a very complex building material and almost impossible of correct analysis, is composed of the above-named elements. What is of far more importance to us is the fact that it is distinguished by certain *properties* which it possesses and which inorganic matter does not possess.

**Properties of Protoplasm.** — The properties of protoplasm are as follows: —

(1) *It is irritable:* it responds to influences or stimuli which come to it from outside its own substance. Both plants and animals are sensitive to touch or stimulation by light, heat, or electricity. Green plants turn toward the source of light. Some animals are attracted, and others are repelled by light.

(2) *Protoplasm has the power to move and to contract.* Muscular movement is a familiar instance of this power. Plants move their leaves and other organs.

(3) *Protoplasm can take in, digest, and make food over into its own substance. This process is known as nutrition.* As a result of this process the organism grows.

(4) *Protoplasm, be it in the body of a plant or of an animal, uses oxygen.* It breathes. Thus substances taken into the body may be oxidized, and release energy for movement and the other activities of plants and animals.

(5) *Protoplasm has the power to rid itself of waste materials,* especially those which might be harmful to it. A tree sheds its leaves, and as a result gets rid of the accumulation of mineral matter in the leaves. Plants and animals alike pass off the carbon dioxide which results from the very processes of living, the oxidation of parts of their own bodies. Animals eliminate wastes containing nitrogen through the skin and the kidneys.

(6) *Protoplasm can reproduce, that is, form other matter like itself.* New plants are constantly appearing to take the places of those that die. The supply of living things upon the earth is not decreasing; reproduction is constantly taking place.

(7) Protoplasm has, as we shall see later, certain other physical properties which help explain certain functions of plants and animals.

**Summary.** — To sum up, we find that living protoplasm has the properties of sensibility, motion, growth, and reproduction both in its simplest state as a one-celled plant or animal and when it enters into the composition of a highly complex organism such as a tree, a dog, or a man. The cells in these organisms have the same general structure in plants as in animals (with the exception of certain minor differences that we shall see later). Protoplasm is composed of the same chemical elements that are found in the air, water, soil, and in organic foods. How protoplasm is made from non-living matter is a wonderful story, a part of which we shall hear later.

**Problem Questions.** — 1. Why are living things called organisms?

2. Explain the terms function, adaptation, organ, tissue.
3. Describe from the diagrams a cell and show how it divides.
4. What is the chemical composition of protoplasm?
5. Discuss the properties of protoplasm.

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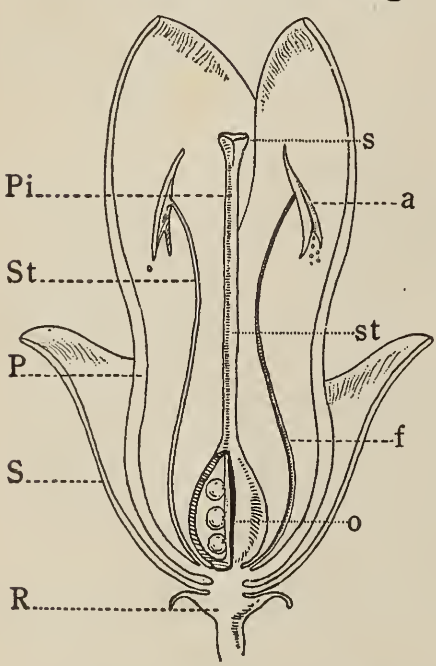
# IV. FLOWERS AND THEIR WORK

***Problem.*** *The structure and work of the parts of a flower. (Laboratory Manual, Prob. VI; Laboratory Problems, Probs. 12, 21, 22.)*

**Structure of a Simple Flower.**—You have all seen in winter a branch of a tree bearing buds. It would not be difficult to imagine that some of the buds are to form branches while others form flowers. Such is really the case. A flower is a shortened branch made for the purpose of producing seeds for the plant. Our problem will be to learn something of the structure and uses of the parts of a very simple flower. The expanded portion of the flower stalk, which holds the parts of the flower, is called the *receptacle.*

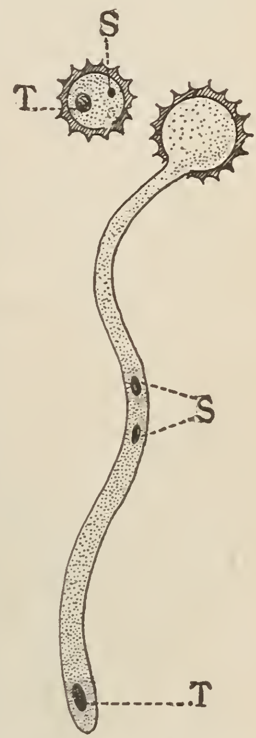



A typical flower, cut lengthwise to show all parts. Compare with the picture of a flower on page 31. *R*, receptacle; *S*, sepal; *P*, petal; *St*, stamen; *Pi*, pistil. The stamen consists of a stalklike filament *f* and a boxlike anther *a*, which holds the pollen. The pistil is made up of an enlarged ovary *o*, a stalk or style *st*, and a terminal stigma *s*.

*The Floral Envelope.*— The small green leaflike parts covering the unopened flower are called *se′pals.* All together they make the *calyx* (kā′lix). The sepals come out in a circle or *whorl* on the flower stalk. The more brightly colored structures are the *pet′als.* They form the *corol′la.* The corolla is of importance, as we shall see later, in making the flower conspicuous.

*The Essential Organs.*— A flower, however, could live without sepals or petals and still produce seeds, the work for which it

exists. *The essential organs* of the flower are within the so-called floral envelope. They consist of the *stamens* (stā′menz) and *pistil,* the latter being in the center of the flower. The stamens have knobbed ends and are arranged in a circle around the pistil. The stalk of the stamen is called the *fil′ament* and the knobbed end is the *an′ther,* which is in reality a hollow box which produces a large number of little grains called *pol′len.* It is necessary for the reproduction of new plants that the pollen grains get out of the anther. Each pistil is composed of a rather stout base called the *o′vary,* containing the *o′vules* which later may form the *seeds,* a stalklike structure called the *style,* and the *stigma,* which is the upper end of the style, and in some cases is broadened. The surface of the stigma usually secretes a sweet fluid in which grains of pollen from flowers of the same kind can grow.



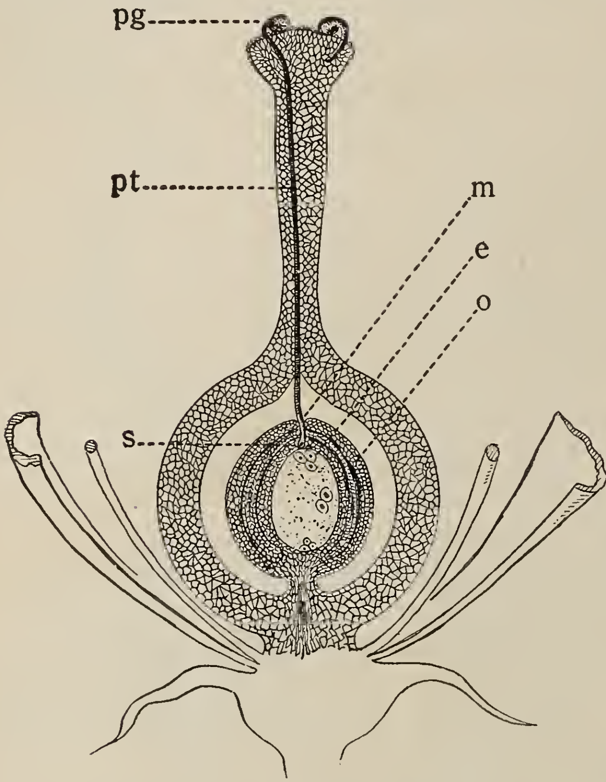
Pollen grains, in section; one is germinating. *T,* tube nucleus; *S,* sperm nuclei.

**Pollen.** — Pollen grains of various flowers, as seen under the microscope, differ greatly in form and appearance. Some are relatively large, some small, some rough, others smooth, some spherical, and others angular. They all agree, however, in having a thick wall, with a thin membrane under it, the whole inclosing a mass of protoplasm. At an early stage the pollen grain contains but a single cell. Later, however, we can distinguish two nuclei in the protoplasm.

**Growth of Pollen Grains.** — Under certain conditions a pollen grain will germinate; that is, burst open and grow a threadlike projection called the *pollen tube;* see Figure. Two nuclei enter this tube. One of them, the *tube nucleus,* disappears after a time. The second, germinative nucleus, divides to form two *sperm nuclei.*

**Fertilization of the Flower.** — If we cut the pistil of a large flower (as a lily) lengthwise, we notice that the style appears to be composed of rather spongy material in the interior; the ovary is hollow and is seen to contain a number of rounded

structures which appear to grow out from the wall of the ovary. These are the *ovules.* The ovules, under certain conditions, become *seeds.* An explanation of these conditions may be had if we examine, under the microscope, a very thin section of a pistil on which pollen has begun to germinate. The central part of the style is found to be either hollow or composed of a soft tissue through which the pollen tube can easily grow. Upon germination, the pollen tube grows downward through the spongy center of the style, follows the path of least resistance to the space within the ovary, and there enters an ovule. It is believed that some chemical influence attracts the pollen tube. The sperm cell penetrates an ovule by making its way through the hole made by the pollen tube, called the *micropyle* (mī′crŏ-pīl), and then grows toward a clear bit of protoplasm known as the *em′bryo sac.* The embryo sac is an ovoid space, microscopic in size, filled with semifluid protoplasm containing several nuclei. (See Figure.) *One of the nuclei, with the protoplasm immediately surrounding it, is called the egg cell.* It is this cell that the sperm cell of the pollen tube grows toward; ultimately the sperm cell reaches the egg cell and unites with it. *The union of the nucleus of the sperm cell with the nucleus*




A flower cut lengthwise to illustrate fertilization: *pg*, germinating pollen grain which forms a pollen tube *pt* and grows down through the spongy style and through the micropyle *m* into the embryo sac within the ovary *o*. The sperm nucleus *s* is about to unite with an egg nucleus *e* to form a fertilized egg.

*of the egg cell in the ovary is known as fertilization.* The single cell formed by the union of the sperm cell and the egg cell is now called a *fertilized egg.*

When the two cells unite to form a fertilized egg, this egg, by constant divisions of the cells, forms an *embryo* or baby plant. This is contained in the seed and, as we know, will develop into an adult plant if given proper environmental conditions.

**Problem.** *A study of cross-pollination and some means of bringing it about. (Laboratory Manual, Prob. VII; Laboratory Problems, Probs. 13, 14, 15.)*

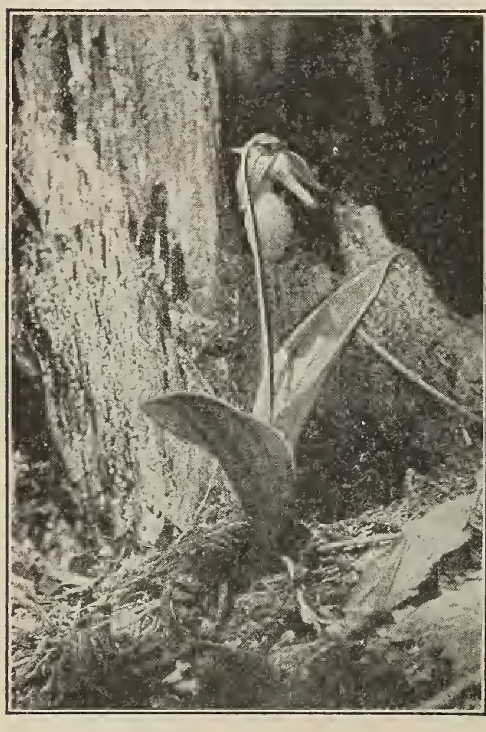
(*a*) *Adaptations in the flower.*

(*b*) *Adaptations in an insect agent.*

(*c*) *Other agents.*

**History of the Discoveries regarding Pollination of Flowers.** — Although the ancient Greek and Roman naturalists had some vague ideas on the subject of fertilization, it was not until the latter part of the eighteenth century that it was demonstrated that pollen is necessary for the growth of the embryo within a seed. In the latter part of the eighteenth century a book appeared in which a German named Conrad Sprengel worked out the facts that the structure of certain flowers seemed to be adapted to the visits of insects. Certain facilities were offered to an insect in the way of easy foothold, sweet odor, and especially food in the shape of pollen and nectar, the latter a sweet-tasting substance manufactured by certain parts of the flower known as the nectar glands. Sprengel further discovered the fact that pollen could be and is carried by the insect visitors from the anthers of the flower to its stigma. It was not until the middle of the nineteenth century, however, that an Englishman, Charles Darwin, worked out the true relation of insects to flowers by his investigations upon the cross-pollination of flowers. *By pollination we mean the transfer of pollen from an anther to the stigma of a flower. Self-pollination is the transfer of pollen from the anther to the stigma of the same flower; cross-pollination is the transfer of pollen from the anthers of one flower to the stigma of another flower of the same kind.* Many

species of flowers are self-pollinated and do not do as well in seed production if cross-pollinated, but Charles Darwin found that some flowers which were self-pollinated did not produce as many seeds, and that the plants which grew from their seeds were smaller and weaker than plants from seeds produced by cross-pollinated flowers of the same kind. He also found that plants grown from cross-pollinated seeds tended to *vary* more than those grown from self-pollinated seed. This has an important bearing, as we shall see later, in the production of new varieties of plants. Microscopic examination of the stigma at the time of pollination also shows that the pollen from another flower germinates more quickly than the pollen which has fallen from the anthers of the same flower. This latter fact in most cases renders it unlikely for a flower to produce seeds by its own pollen. Darwin worked for many years on the pollination of many insect-visited flowers, and discovered in almost every case that showy, sweet-scented, or otherwise attractive flowers were adapted or fitted to be cross-pollinated by insects. He also found that, in the case of flowers that were inconspicuous in appearance, often a compensation appeared in the odor which rendered them attractive to certain insects. The so-called carrion flowers, pollinated by flies, are examples, their odor being like that of decayed flesh. Other flowers, which open at night, are white and provided with a powerful scent so as to attract night-flying moths and other insects. Flowers adapted to be cross-pollinated by insects are

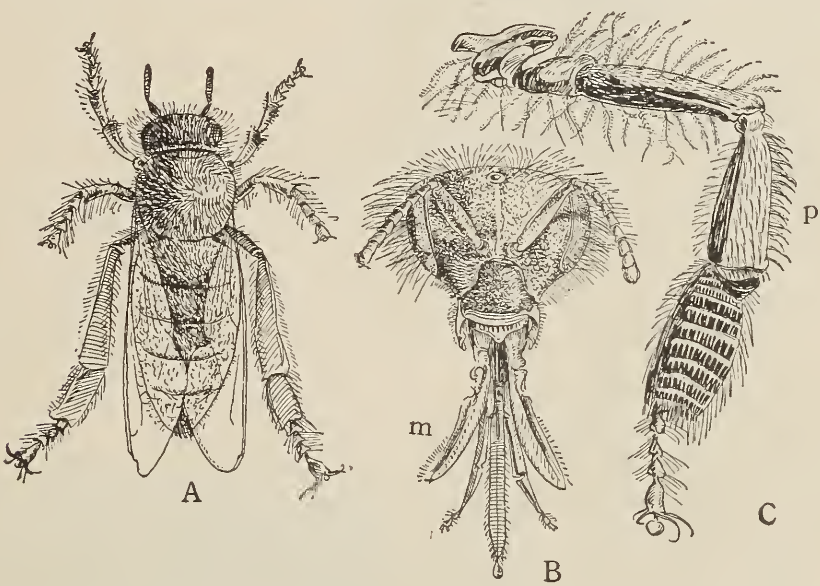


A wild orchid, a flower of the type from which Charles Darwin worked out his theory of cross-pollination by insects.

frequently irregular in shape. Thus butter and eggs is a flower which is well fitted for cross-pollination by insects.

**Suggestions for Field Work.** — At this point, at least one field trip should be introduced for the purpose of studying under natural conditions the cross-pollination of flowers by insects. Directions for a field trip will be found in Hunter's *Laboratory Problems in Civic Biology*, pages 39–43.

**Insects as Pollinating Agents.** — No one who sees a hive of bees with their wonderful communal life can fail to realize that these insects play a great part in the life of the flowers near the




The bee is adapted for carrying pollen. How? *A*, dorsal view of bee; *B*, front view of head; *m*, mouth parts; *C*, a leg, showing the pollen basket *p*. Note the feathery hairs on the upper joints of the leg.

hive. A famous observer named Sir John Lubbock tested bees and wasps to see how many trips they made daily from the hive to the flowers, and found that the wasp went out on 116 visits during a working day of 16 hours, while the bee made almost as many visits, and worked only a little less time than the wasp worked. It is evident that in the course of so many trips to the fields a bee must light on and cross-pollinate many hundreds of flowers.

**Study of a Bee.** — The body of a bee (and of all other insects) is divided into three parts. Attached to the middle part (the

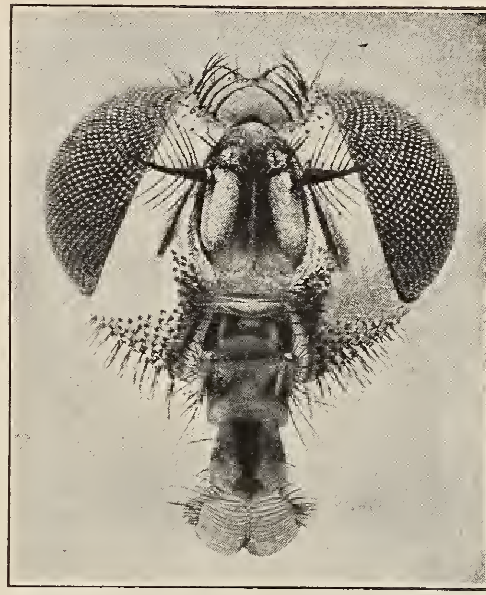
*tho'rax*) are three pairs of jointed legs and two pairs of tiny wings. By the legs and the jointed body we are able to distinguish insects from other animals. If we look closely at the bee, we find the body and legs more or less covered with tiny hairs; especially are these hairs found on the legs. *When a plant or animal structure is fitted to do a certain kind of work, we say it is adapted to do that work.* The joints in the leg of the bee adapt it for complicated movements; the arrangement of stiff hairs along the edge of a concavity in one of the joints of the leg forms a structure well fitted to hold pollen. In this basket pollen is collected by the bee and taken to the hive to be used as food. But while gathering pollen for itself, the bee catches pollen on the hair and other projections on its body and legs and carries it from flower to flower. Thus cross-pollination may be effected.

**Pollination not intended by the Bee.** — The cross-pollination of flowers is not planned by the bee; it is simply an incident in the course of the food gathering. The bee visits a large number of flowers of the same species during the course of a single trip from the hive, and it is then that cross-pollination takes place.

**Suggestions for Field Work.** — In any locality where flowers are abundant, try to answer the following questions: How many bees visit the locality in ten minutes? How many other insects alight on the flowers? Do bees visit flowers of the same kind in succession, or fly from one flower on a given plant to another on a plant of a different kind? If the bee alights on a flower cluster, does it visit more than one flower in the same cluster? How does a bee alight? Exactly what does the bee do when it alights? Try to decide whether color or odor has the most effect in attracting bees to flowers. Sir John Lubbock tried an experiment which it would pay a number of careful pupils to repeat. He placed a few drops of honey on glass slips and placed them over papers of various colors. In this way he found that the honeybee, for example, could evidently distinguish different colors. Bees seemed to prefer blue to any other color. Flowers of a yellow or flesh color were preferred by flies. It would be of considerable interest for some student to work out this problem with our native bees and with other insects. Test the keenness of sight in insects by placing a white object (a white golf ball will do) in the grass and see how many insects will alight on it. Try to work out some method by which you can decide whether a given insect is attracted to a flower by odor alone.

**The Sight of the Bumblebee.** — The large eyes located on the sides of a bee's head are made up of a large number of little units,

each of which is considered to be a very simple eye. The large eyes are therefore called the *compound eyes.* All insects are provided with compound eyes, with simple eyes, or, in most cases, with both. The simple eyes of the bee may be found by a careful observer between and above the compound eyes.



Front view of the head of a fly. The compound eyes are at the sides. Photograph from American Museum of Natural History, New York.

One would suppose that with so many eyes the sight of insects would be extremely keen, but such does not seem to be the case. Insects can, as we have already learned, distinguish differences in color at some distance; they can see *moving* objects, but they do not seem to be able to make out form well. To make up for this, they appear to have an extremely well-developed sense of smell. Insects can distinguish at a great distance odors which to the human nose are imperceptible. Night-flying insects, especially, find the flowers by the odor rather than by color.


A lily: *P*, petal; *S*, stamen (anther); *SEP*, sepal; *St*, pistil (stigma). Notice the nectar guides on the petals.

**Nectar and Nectar Glands.** — The bee is attracted to a flower for food. This food may consist of pollen or *nec'tar.* Nectar is a sugary solution that is formed in the flower by little collections of cells called the *nectar glands.* The nectar glands are usually so placed that to reach

them the insect must first brush the stamens and pistil of the flower. Frequently the location of the nectaries (nectar glands) is made conspicuous by brightly colored markings on the corolla of the flower. The row of dots in the tiger lily is an example.

**Mouth Parts of the Bee.** — The mouth of the bee is adapted to take in the foods we have mentioned, and is used in this way, for the same purposes that a man would use the hands and fingers. The honeybee laps or sucks nectar from flowers, it chews the pollen, and it uses part of the mouth as a trowel in making the honeycomb. A glance at the Figure, page 29, shows us that the mouth parts of the bee are complex. The parts consist of a pair of very small jaws or mandibles, certain other structures, *max-il'læ*, part of the lower lip called the *labial palps*, and a long tongue-like structure called the *lig'ula*. The uses of the mouth parts may be made out by watching a bee on a well-opened flower.

Long-billed humming birds: above, one at rest; below, one gathering nectar. Photograph from American Museum of Natural History.

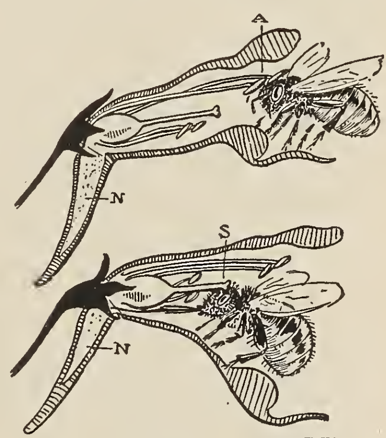
**Other Flower Visitors.** — Other insects besides the bee are pollen carriers for flowers. Among the most useful are moths and butterflies. Both of these insects feed only on nectar, which they suck through a long tubelike *proboscis* (pro-bŏs'is). The heads and bodies of these insects are more or less thickly covered with hairs, and the wings are thatched with tiny hairlike scales. All these structures are of some use to the flower because they collect and carry pollen; but the palp, a fluffy structure projecting from each side of the head of a butterfly, collects a large amount of pollen, which is deposited upon the stigmas of other flowers when the butterfly pushes its head down into the flower tube after nectar.

Flies and a few other insects are agents in cross-pollination. Humming birds (picture, p. 32) are also active agents in some flowers. Snails are said in rare instances to carry pollen. Man and the domesticated animals pollinate a few flowers by brushing past them through the fields.

**Butter and Eggs.** — From July to October butter and eggs, a very abundant weed, may be found especially along roadsides and in sunny fields. It bears a tall and conspicuous flower cluster known as a *spike*, the yellow and orange flowers being arranged so that they come out directly from the main flower stalk.

The corolla projects into a spur on the lower side; an upper two-parted lip shuts down upon a lower three-parted lip. The four stamens are in pairs, two long and two short.

Certain parts of the corolla which are more brightly colored than the rest of the flower, serve as a guide to insects. This flower is visited most frequently by bumblebees, which are guided by the orange lip to alight just where they can push their way into the flower. The bee, seeking the nectar secreted in the spur, brushes its head and shoulders against the anthers. On visiting another flower of the cluster, it would be an easy matter accidentally to transfer this pollen to the stigma of that flower. In this way cross-pollination is effected.



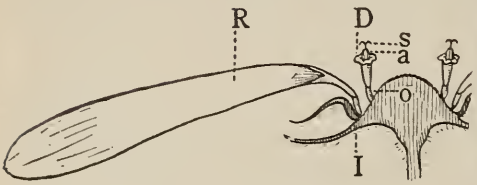

Cross-pollination of butter and eggs by a bumblebee: *A*, anther; *S*, stigma; *N*, nectar spur.

Insects may also cause self-pollination by rubbing against the upper pair of stamens, thus depositing some pollen on the stigma as they back out of the flower.

**Cross-pollination of a Head (Clover).** — In a head, which is a closely massed cluster of little flowers, as the clover, cross-pollination is usually effected by bumblebees which rapidly work from one flower to another in the same group, inserting their tongues deep into the flower cups.

**Cross-pollination of a Composite Head.** — The composite head is made clear by a daisy, aster, or sunflower. This head has an

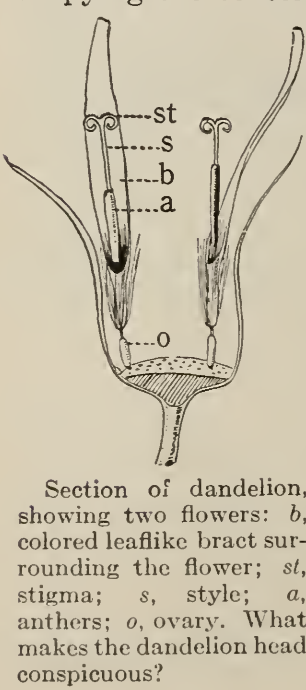
outer circle of green parts which look like sepals, but in reality are a whorl of leaflike parts. Taken together these form an




Section of daisy; a composite head. *R*, ray flower; *D*, disk flower; *I*, involucre; *s*, stigma; *a*, anthers; *o*, ovary.

Composite head. Photograph of gaillardia by Albert E. Butler, from American Museum of Natural History, New York.

*involucre* (ĭn′vo-lu-ker). Inside the involucre is a whorl of brightly colored, irregular flowers called the *ray flowers.* They appear to act, in some instances at least, as an attraction to insects by showing a definite color (see the common dogwood). The flowers occupying the center of the cluster are the *disk flowers.* Pollen is carried easily from one flower to another even by an insect which crawls.

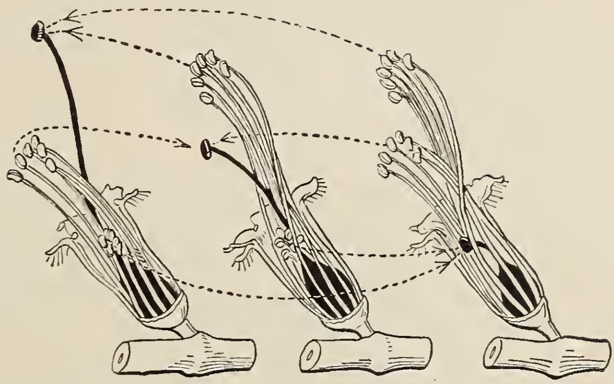



Section of dandelion, showing two flowers: *b*, colored leaflike bract surrounding the flower; *st*, stigma; *s*, style; *a*, anthers; *o*, ovary. What makes the dandelion head conspicuous?

**Adaptations to prevent Self-pollination.** — In some flowers, as is shown by the primulas of our hothouses, the stamens and pistils are each of two different lengths in different flowers. Short styles and long or high-placed filaments are found in one flower, and long styles with short or low-placed filaments in another. Pollination is most likely to be effected by some of the pollen from a low-placed anther reaching the stigma of a short-styled flower, or by the pollen from a high anther being placed upon a long-styled pistil. Flowers which have this peculiar condition are said to be *dimorphic*

(Greek = of two forms). There are, as in the case of the loosestrife, *trimorphic* flowers, having pistils and stamens of three lengths.

In many kinds of flowers we find that the stamens ripen before the pistils, or just the opposite may happen. Such a condition effectually prevents self-pollination. This condition is called *dichogamy* (dī-cŏg′a-mĭ).



Stamens (light) and pistils (dark), and course of cross-pollination in loosestrife, a trimorphic flower.

**Other examples.** — Many other examples of adaptations to secure cross-pollination by means of the visits of insects might be given. The mountain laurel, which makes our hillsides so beautiful in late spring, shows a remarkable adaptation in having the stamens caught in little pockets of the corolla. The weight of the visiting insect on the corolla releases the anther of the stamen from the pocket in which it rests, the anther opens, and the body of the visitor is dusted with pollen.

Pronuba pollinating pistil of yucca.

Still another example of cross-pollination is found in the yucca, a desert-loving semitropical lily. In this flower the stigma is above the anther, and the pollen is sticky and could not be transferred except by insect aid. A little moth, called the *pro′nuba*, gathers pollen from an anther, flies away with this load to another flower, there deposits eggs in the ovary of the pistil, and then rubs its load of pollen over the stigma of the flower. The young hatch out and feed on some of the young seeds which have been fertilized by the pollen placed on the stigma by the mother, and then bore out of the seed pod and escape to the ground, leaving the plant to develop the remaining seeds without further molestation.

The pollination of the fig shows another wonderful example

of adaptation The fig is not a fruit but a cluster of fruits, growing inside the inturned ends of a fleshy flower stalk. There may be three kinds of flowers in the clusters, some bearing stamens only, some with pistils only with long styles, and others with short styles. Some fig flower clusters have long-styled pis′tillate flowers only, others contain both short-styled and stam′inate flowers, the latter above the pistillate flowers. All of these flowers are visited by a little wasp. When it visits the short-styled and staminate fig it lays its eggs in the ovary, which it can easily reach with its egg-depositing organ (the ovipositor). The females which hatch work their way out and in doing so brush against the staminate flowers, thus collecting pollen on their bodies. They then seek other figs in order to lay their eggs. If a wasp reaches another short-styled flower cluster the eggs are laid and development takes place as before. But if it flies to a long-styled cluster it cannot reach the ovary to deposit its eggs. In both cases, however, the wasp has carried pollen to the stigma and pollination takes place with the subsequent development of seeds. The figs we eat are the ones developed from the long-styled pistillate flowers.

**Pollination by the Wind.** — Not all flowers are dependent upon insects for cross-pollination. Many of the earliest spring flowers appear almost before the insects do. In many trees, such as the oak, poplar, and maple, the flowers open before the leaves come out. Such flowers are dependent upon the wind to carry the pollen from the stamens of one flower to the pistil of another.

Among the adaptations that a wind-pollinated flower shows are: (1) The development of very many pollen grains to each ovule. In one of the insect-pollinated flowers, that of the night-blooming cereus, the ratio of pollen grains to ovules is about eight to one. In flowers which are to be pollinated by the wind, a large number of the pollen grains never reach their destination and are wasted. Therefore in these plants several thousands, perhaps hundreds of thousands, of pollen grains will be developed to every ovule produced. Such are the pines. In May and early June the ground under pine trees is often yellow with pollen, and the air is filled with the pollen dust for miles

from the trees. The same is true, also, with many of the grasses, including corn or maize.

(2) The anthers are usually held high and exposed to the wind when ripe. The common plantain and timothy grass are excellent examples.

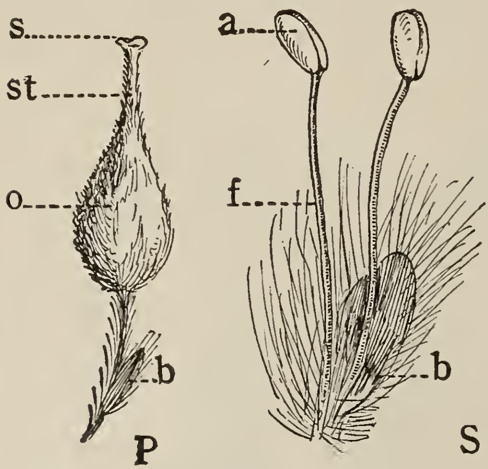

Cross-pollination of corn by the wind.

(3) The pistil of the flower is peculiarly fitted to retain the pollen by having feathery projections along the sides which increase the surface of the stigma. This can be seen in grasses. In the Indian corn the stigma is the so-called silk which protrudes beyond the covering of modified leaves which form the husk of the ear of corn. All our grains, wheat, rye, oats, and others, have the typical feathery pistil of the wild grasses from which they have been developed.

(4) The corolla is often entirely lacking. It would only be in the way in flowers that are dependent upon the wind to carry pollen.

**Imperfect Flowers.** — Some flowers, the wind-pollinated ones in particular, are imperfect; that is, they lack either stamens or pistils. In such flowers, cross-pollination must of necessity be depended upon. If only stam′inate flowers (those which contain only stamens) are developed on one plant, and only

pis′tillate flowers (those which bear only pistils) on another, we call the species *diœcious* (dī-ē′shus). A common example is the willow.



Pistillate flower *P*, and staminate flower *S*, of the willow; *b*, bract; *o*, ovary; *st*, style; *s*, stigma; *f*, filament; *a*, anther.

Other species have staminate and pistillate flowers on the same plant. In this case they are said to be *monœcious* (mō-nē′shus). The oak, hickory, beech, birch, walnut, and chestnut are familiar examples.

**Protection of Pollen.** — Pollen, in order to be carried effectively by the wind, insects, or other agencies, must be dry. In some flowers the irregular form of the corolla protects the pollen from dampness. Other flowers close up at night, as the morning-glory and four-o'clock. Still others, as the bellflower, droop during a shower or at night.

Pollen is also protected from insect visitors as ants, plant lice, or other small crawling insects which would carry off pollen but give the flower no return by cross-pollinating it, by hairs which are developed upon the filaments or on the corolla. Sometimes a ring of sticky material is found making a barrier around the stalk underneath the flower. Many other adaptations of this sort might be mentioned.

**Artificial Cross-pollination and its Practical Benefits to Man.** — Artificial cross-pollination is practiced by plant breeders and can easily be tried in the laboratory or at home. First the anthers must be carefully removed from the bud of the flower so as to eliminate all possibility of self-pollination. The flower must then be covered so as to prevent access of pollen from without; when the pistil is sufficiently developed, pollen from another flower, having the characteristics desired, is placed on the stigma and the flower again covered to prevent any other pollen reaching the flower. The seeds from this flower when planted *may* give rise to plants with some characteristics of each of

the plants from which the pollen and egg cell came. Naturally the two plants cross-pollinated must be of the same or of closely allied species. If they are of different species or varieties, the new plants produced are called *hy'brids*. It is this kind of work that made Luther Burbank famous. An excellent project report might be made on his work by reading Harwood's *New Creations in Plant Life*.

**Summary.** — In summarizing this chapter we find (1) that seeds are produced as a result of the fertilization of the egg cell by the sperm cell in the ovary of a flower; (2) this is brought about by pollination; (3) pollination may be self (within the flower) or cross (from the anthers of one flower to the stigma of another flower, usually of the same species); (4) that insects as well as other agents may bring this about; and (5) that there are many adaptations within flowers to prevent self-pollination, the chief of which are:

*The stamens and pistils may be found in separate flowers, either on the same or on different plants.*

*The stamens may produce pollen before the pistil of the same flower is ready to receive it, or vice versa.*

*The stamens and pistils may be so placed with reference to each other that pollination can be brought about only by outside assistance.*

**Problem Questions.** — 1. What is the use of a flower?

2. What is fertilization? How is it accomplished in a flower?

3. Mention some adaptation in insects to help bring about cross-pollination in flowers.

4. Discuss three types of adaptations to insure cross-pollination in flowers.

5. What are some practical benefits from cross-pollination?


Problem and Project References

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# V. FRUITS AND THEIR USES

***Problem.*** *A study of fruits to discover —*

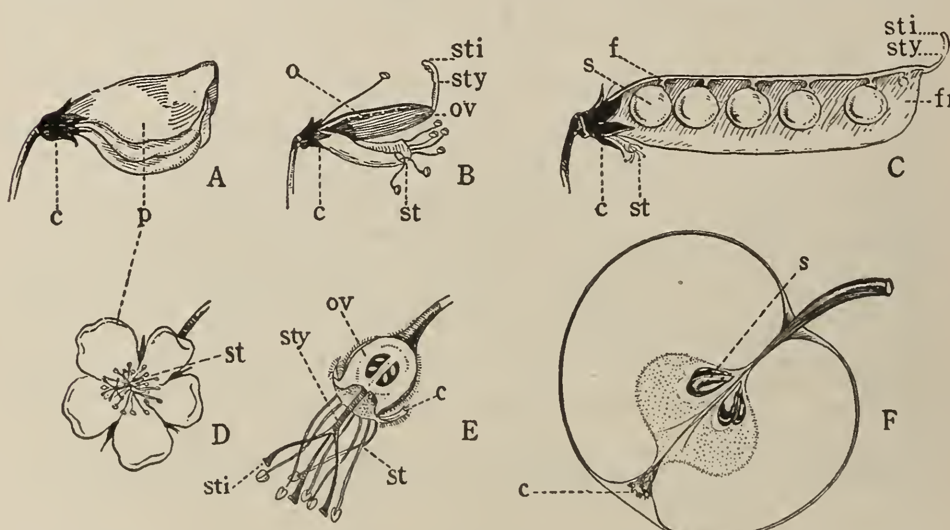
(*a*) *Their uses to a plant.*

(*b*) *How they are scattered.*

(*c*) *Their protection from animals and other enemies.*

(*Laboratory Manual, Prob. VIII; Laboratory Problems, Probs. 23, 24.*)

**A Typical Fruit, — the Pea or Bean Pod.** — If a withered flower of any one of the pea or bean family is examined carefully it will be found that the pistil of the flower continues to grow after the rest of the flower withers. If we examine the pistil from such a flower we find that it is the ovary that has enlarged. The space within the ovary has become almost filled




*A*, *B*, *C*, stages in the formation of fruit of pea; *D*, *E*, *F*, corresponding stages in apple fruit; *c*, calyx; *p*, petals; *st*, stamens; *sti*, stigma; *sty*, style; *ov*, ovary; *f*, funiculus; *fr*, valve of pod; *s*, seed.

with a number of ovoid bodies, attached along one edge of the inner wall. These we recognize as the young seeds.

The pod of a bean, pea, or locust illustrates well the growth from the flower. The flower stalk, the ovary, and the remains of the style, the stigma, and the calyx, can be found on most

unopened pods. If the pod is opened, the seeds will be found fastened to the ovary wall each by a little stalk called the *funic'ulus*. That part of the ovary wall which bears the seeds is the *placen'ta*. The walls of the pod are called *valves*.

The pod, which is in reality a ripened ovary with other parts of the flower attached to it, is considered a *fruit*. By definition, *a fruit is a ripened ovary together with any parts of the flower that may be attached to it*. The chief use of the fruit is to hold and to protect the seeds; it may ultimately distribute them where they can reproduce young plants.

**Formation of Seeds.** — *Each seed has been formed as a direct result of the fertilization of the egg cell (contained in the embryo sac of the ovule) by a sperm cell of the pollen tube.*

Young pine trees near the parent tree. Photograph from U. S. Department of Agriculture.

**Seed Dispersal.**[1] — If you will go out any fall afternoon into the fields, a city park, or even a vacant lot, you can hardly

[1] At this point a field trip may well be taken with a view to finding out how the common fall weeds scatter their seeds. Fruits and seeds obtained upon this trip will make a basis for laboratory work on the adaptations of seed and fruit for dispersal.

escape seeing how seeds are scattered by the parent plants and trees. Several hundred little seedling trees may be counted often under the shade of a single maple or oak tree. But nearly all these young trees are doomed to die, because of the overshading and crowding. Plants, like animals, are dependent upon their surroundings for food and air. They need light even more than animals need it, because the soil directly under the shade of the old tree gives only raw food material to the plants, and they must have sunlight in order to make food. This overcrowding is seen in the garden where young beets or lettuce plants are growing. The gardener assists nature by thinning out the young plants so that they may not be handicapped in their battle for life in the garden by an insufficient supply of air, light, and food.

It is evidently of considerable advantage to a plant to be able to place its progeny at a considerable distance from itself, in order that the young plants may be provided with sufficient space to get nourishment and foothold. This is the result which plants have to accomplish. Some accomplish the result more completely than others, and thus are the more successful ones in the battle of life.


The blackberry, a fruit having small seeds scattered by birds.

**Adaptations for Seed Dispersal; Fleshy Fruits with Hard Seeds.** — Plants are fitted to scatter their seeds by having the special means either in the fruit or in the seed. Various agents, as the wind, water, or squirrels, birds, and other animals, make it possible for the seeds to be taken away from the plant.

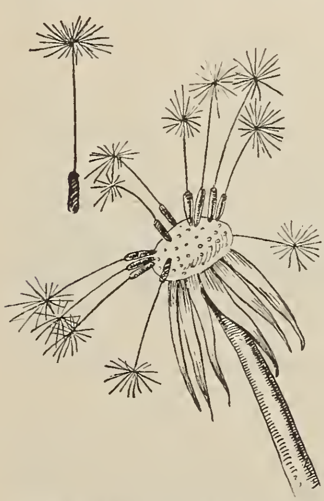
Fleshy fruits, that is, such fruits as contain considerable water when ripe, are eaten by animals and the seeds passed off undigested. Most wild fleshy fruits have small, hard, indigestible seeds. Birds are responsible for much seed planting of berries and other small fruit. Bears and other berry-eating animals aid

in this as well. Some seeds have especial adaptations in the way of spines or projections. Insects make use of these projections in order to carry them away. Ants plant seeds which they have carried to their nests for a food supply. Nuts are planted by squirrels and blue jays.

**Suggestions for Field Work.** — Examine the fruit of huckleberry, blackberry, wild strawberry, wild cherry, black haw, wild grape, tomato, currant. Report how many of the above have seeds with hard coatings. Notice that in most, if not in all, edible fruits, the fruit remains green, sour, and inedible until the seeds are ripe. In the state of nature, how might this be of use to a plant?

**Hooks and Spines.** — Some fruits which are dry and have a hard external covering when ripe possess hooks or spines which enable the whole fruit to be carried away from the parent plant by animals or other moving objects. Cattle are responsible for the spread of some of our worst weeds in this way. The burdock and clotbur are familiar examples. In both the mass of little hooks is all that remains of an involucre. Thus the whole fruit cluster may be carried about and seeds scattered. In many of the Composites, as in the cocklebururs and beggar's-ticks, the fruits are provided with strong curved projections which bear many smaller hooklike barbs.

Cocklebur. Notice the curved hooks.

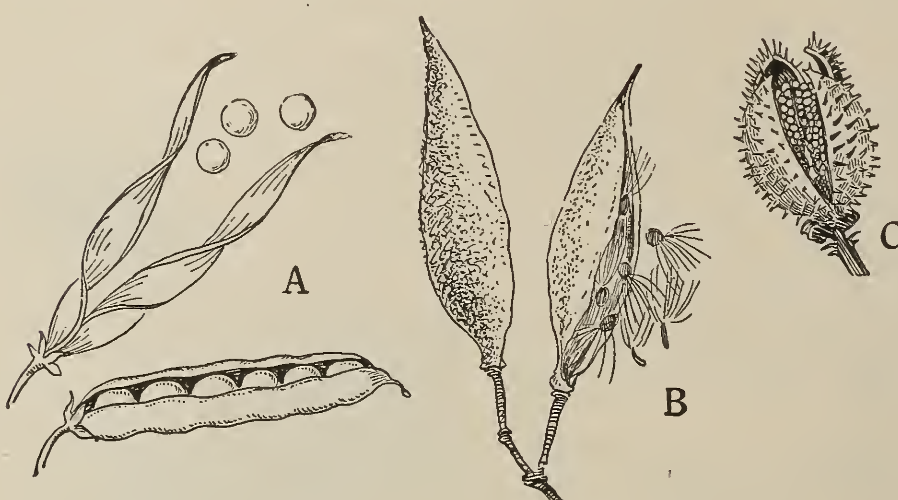


Dispersal of dandelion fruits.

**Pappus.** — Probably the most important adaptations for dispersal of seeds are those by which the fruit is fitted for dispersal by the wind. That much-loved and much-hated weed, the dandelion, is an example of a plant in which the whole fruit is carried by the wind. The parachute, or *pappus*, is an outgrowth of the ovary wall. Many other fruits, notably that of the Canada thistle, are provided with the pappus as a means of getting away. In the milkweed the *seeds* have developed a silky outgrowth which

may carry them for miles. In New York city the air sometimes contains the down from these seeds, brought from far over the meadows of New Jersey by the prevailing westerly wind.

**Dehiscent Fruits and how they Scatter Seeds.** — One of the many methods of scattering seeds is seen in dry fruits. These simply split to allow the escape of the seeds. Examples of common fruits that split open, called *dehiscent* (de-hĭs′ent) fruits, are seen in the *fol′licle* of the milkweed, a fruit which splits along the edge of one valve, the pod or *leg′ume* of the pea and the bean,




Dehiscent fruits: *A*, green pea pod, with valves twisting and expelling the seeds; *B*, milkweed follicle; *C*, Jimson weed capsule.

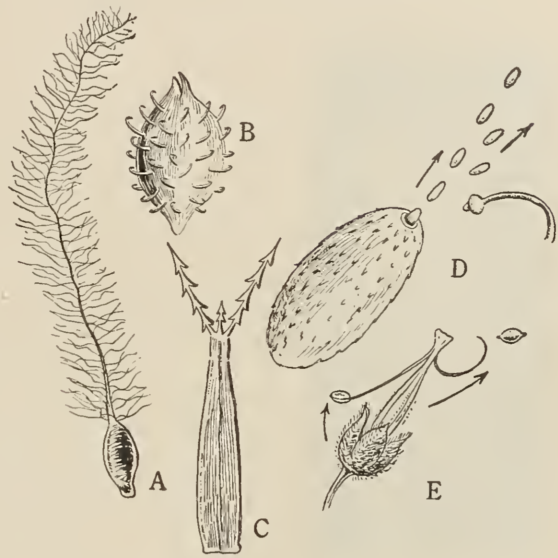
and the *capsule* of Jimson weed and the evening primrose. The wild geranium, a five-loculed capsule, splits along the edge of each locule, snaps back, and throws the seed for some distance. Jewelweed and witch-hazel fruits burst open in a somewhat similar manner.

**Winged Seeds.** — The seeds of the pine, held underneath the scales of the cone, are prolonged into wings, which aid in their dispersal. The seeds of many of our trees are thus scattered. Can you name five trees that have winged seeds?

**Other Methods.** — Sometimes whole plants are carried by the high winds of the fall. The tumbleweed, as it dries, assumes

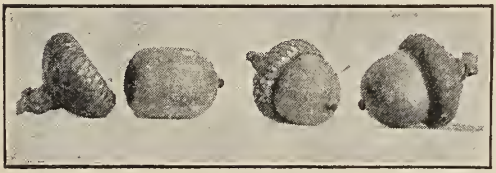
a somewhat spherical shape; the main stalk breaks off, and the plant may then be blown along the ground, scattering seeds as it goes, until it is ultimately stopped by a fence or bush. A single plant of Russian thistle may thus scatter over two hundred thousand seeds.

Seeds or fruits (for example, the coconut) may fall into the water and be carried thousands of miles to their new resting place, the fibrous husk providing a boat in which the seed is carried.




Various methods of seed dispersal: *A*, clematis fruit; *B*, clotbur; *C*, beggar's-tick; *D*, squirting cucumber ejecting seeds after absorbing water until the pressure is sufficient to push out the stopperlike stem; *E*, wild geranium discharging seeds.

Other seeds collect in the mud along the banks of ponds and streams. Birds which come there to feed carry away many seeds in the mud attached to their feet. The great English naturalist, Charles Darwin, raised eighty-two plants from seeds thus carried by a bird. It is probable that most of the vegetation on the newly formed coral islands of the Pacific Ocean has come from seeds brought to them by birds and by water.



The acorn, a nut in which the involucre partly covers the fruit.

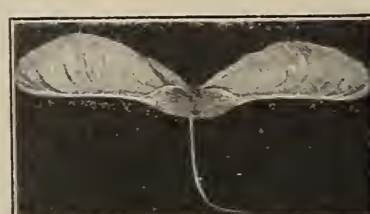
**Indehiscent Fruits.** — Dry fruits which do not split open to allow of the escape of their seeds are known as *in'dehiscent* fruits. Such are nuts, one-seeded fruits with usually hard outer covering, the so-called key fruits of the maple or ash, and many others. Corn, wheat, oats, etc., are indehiscent fruits. A grain is simply a one-seeded fruit in which the wall of the ovary has grown so close to that of the seed that

they cannot be separated. Some indehiscent fruits are light and carried by the wind; others may be scattered by animals.

**Large Numbers of Seeds.** — Plants which do not have especial means for scattering their seeds may make up for this by producing a large number of seeds. The Jimson weed is a familiar example of such a plant. Each capsule of Jimson weed contains from four hundred to six hundred seeds, depending upon its size. If all of these seeds developed, the whole earth would soon be covered with Jimson weed, to the exclusion of all other forms of plant life. That this is not the case is due to the fact that only those seeds which are advantageously placed can develop; the others will, for various reasons (lack of moisture to start the young seed on its way, poor soil, lack of air or sunlight, overcrowding), fail to germinate.


Grain; spikes of ripened flowers.

**The Struggle for Existence.** — Those plants which provide best for their young are usually the most successful in life's race. Plants which combine with the ability to scatter many seeds over a wide territory the additional characteristics of rapid growth, resistance to dangers of extreme cold or heat and to attacks of parasitic enemies, inedibility, and peculiar adaptations to cross-pollination or self-pollination, are usually called weeds. They flourish in the sterile soil of the roadside and in the fertile soil of the garden. By means of rapid growth they kill other plants of slower growth by usurping their territory. Slow-growing plants are thus actually exterminated. Many of our common weeds have been introduced from other countries and have, through their numerous adaptations, driven out other plants which stood in their way. Such is the Russian thistle. First introduced from Russia in 1873, it spread so rapidly that in twenty years it had appeared as a common


Key fruit of maple.

weed over an area of some twenty-five thousand square miles. It is now one of the greatest pests in our Northwest.

**Problem.** *To learn something about the economic value of some fruits. (Laboratory Manual, Prob. IX; Laboratory Problems, Prob. 85.)*

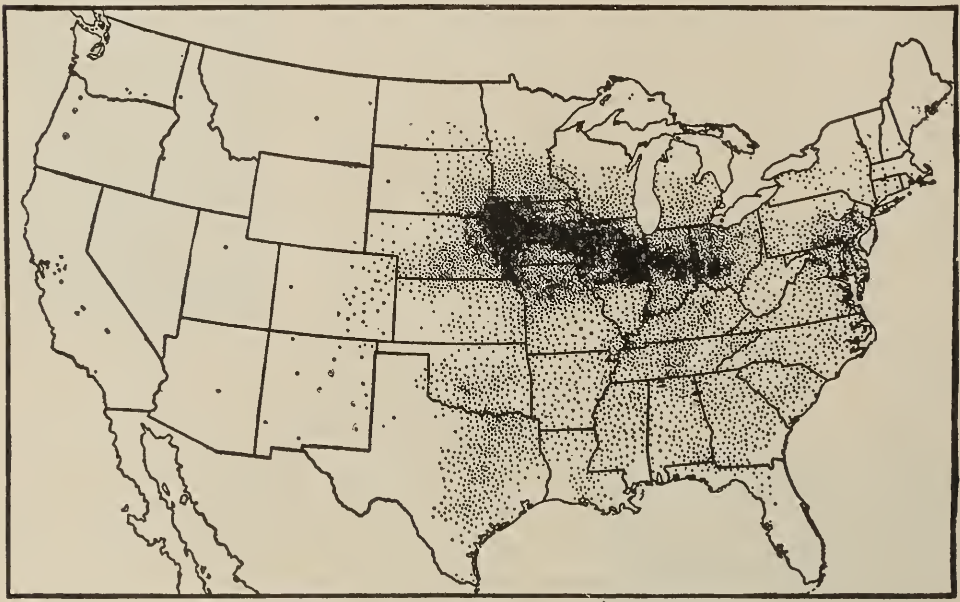
**Economic Value of Grains.** — Our grains are the cultivated progeny of wild grasses. Domestication of plants and animals marks epochs in the advance of civilization. The man of the stone age hunted wild beasts for food, and lived like one of them in a cave or wherever he happened to be; he was a nomad, a wanderer, with no fixed home. He may have discovered that wild roots or grains were good to eat; perhaps he stored some away for future use. Then came the idea of growing things at home instead of digging or gathering the wild fruits from the forest and plain. The tribes which first cultivated the soil made a great step in advance, for they had as a result a fixed place for habitation. The cultivation of grains or cereals gave them a store of food which could be used at times when other food was scarce. The word "cereal" (derived from Ceres, the Roman goddess of agriculture) suggests the importance of this crop to Roman civilization. From earliest times the growing of grain and the progress of civilization have gone hand in hand. As nations have advanced in power, their dependence upon the cereal crops has been greater and greater.

"Indian corn," says John Fiske, in *The Discovery of America*, "has played a most important part in the discovery of the New World. It could be planted without clearing or plowing the soil. There was no need of threshing or winnowing. Sown in tilled land, it yields more than twice as much food per acre as any other kind of grain. This was of incalculable advantage to the English settlers in New England, who would have found it much harder to gain a secure foothold upon the soil if they had had to begin by preparing it for wheat or rye."

To-day, in spite of the great wealth which comes from our mineral resources, live stock, and manufactured products, the surest index of our country's prosperity is the size of the wheat and corn crop.

**Corn.** — More than three billion bushels of corn were raised in the United States in the year 1920. This figure is so enormous that it has but little meaning to us. In the past half century our corn crop has increased over 350 per cent. Illinois and Iowa are the greatest corn-producing states in this country, each having a yearly record of over four hundred million bushels.

Indian corn is put to many uses. It is a valuable food. It has a large proportion of starch, from which glucose and al-

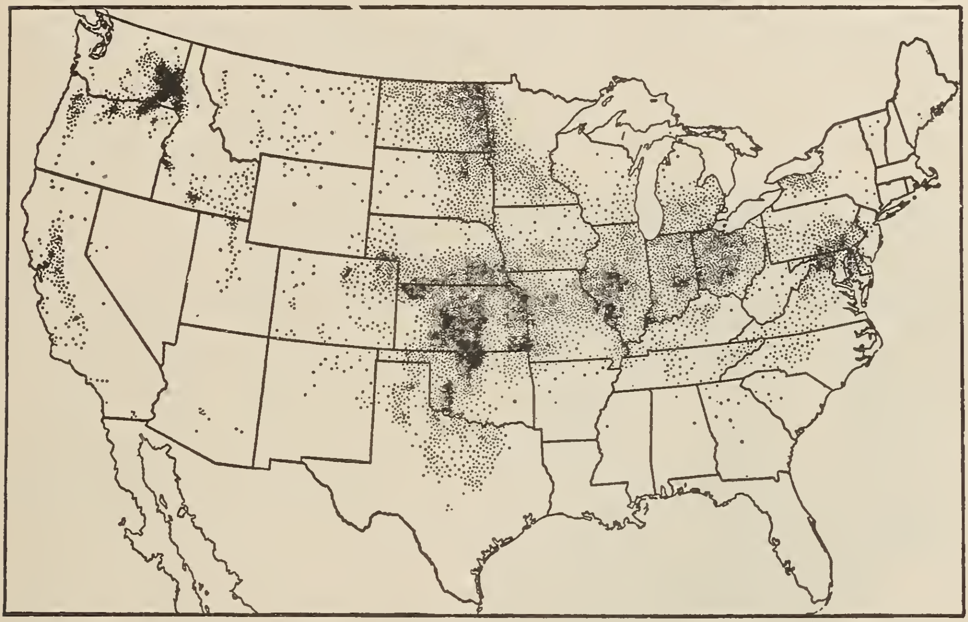


Corn-producing regions in the United States.

cohol are made. It contains some oil, which is used for food, as a lubricant, and for making soap. The leaves and stalk are an excellent fodder; they can be made into paper and packing material. Mattresses can be stuffed with the husks. The pith is used as a protective belt placed below the water line of our huge battleships. Corncobs are used for fuel, one hundred bushels having the fuel value of a ton of coal.

**Wheat.** — Wheat is the crop of next greatest importance in this country. Nearly eight hundred millions of bushels were raised here in 1920, representing a value of nearly $1,000,000,000. Seventy-two per cent of all the wheat raised comes

from the North Central States and California. Much of the wheat crop is exported, nearly half of the exports going to Great Britain. Wheat is used chiefly after being manufactured into flour. The germ, or young wheat plant, is sifted out during this process and made into breakfast foods. Flour-



Wheat-producing regions.

making forms the chief industry of Minneapolis, Minnesota, and of several other large and wealthy cities in this country.

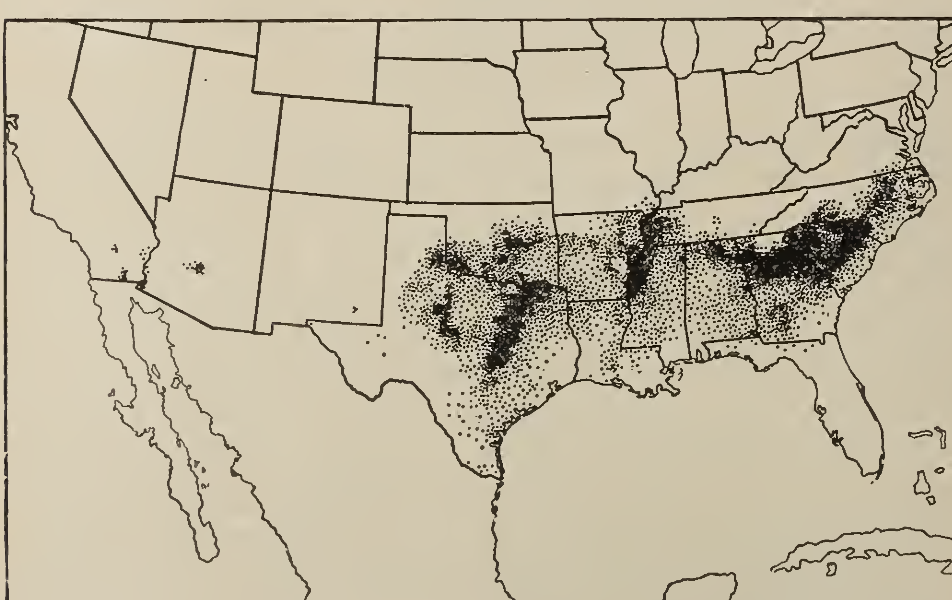
**Other Grains.** — Of the other grains or cereals raised in this country, oats are the most important crop, over one and one half billion bushels having been produced in 1920. Illinois, Wisconsin, Minnesota, and Iowa together produce over 50 per cent of the total yield. Oats are distinctly a northern crop, over 95 per cent being grown north of the parallel of 36°. Barley is a staple of some of the northern countries of Europe and Asia. Although a hardy cereal, almost three fourths of the total production in the United States comes from California, Minnesota, Wisconsin, Iowa; the production of these states may be roughly estimated as 200,000,000 bushels.

Rye is the most important cereal crop of northern Europe,

Russia, Germany, and Poland producing over 50 per cent of the world's supply. It makes the principal food for probably one third the people of Europe, being made into "black bread." It is of relatively less importance as a crop now in the United States than in former years, only 70,000,000 bushels being produced in 1920.

Perhaps one of the most important grain crops for the world, although relatively unimportant in the United States, is rice. Its fruit, after threshing, screening, and milling, forms the principal food of one third of the human race. Moreover, its stems furnish straw, its husks make a bran used as food for cattle, and the grain, when distilled, is rich in alcohol.

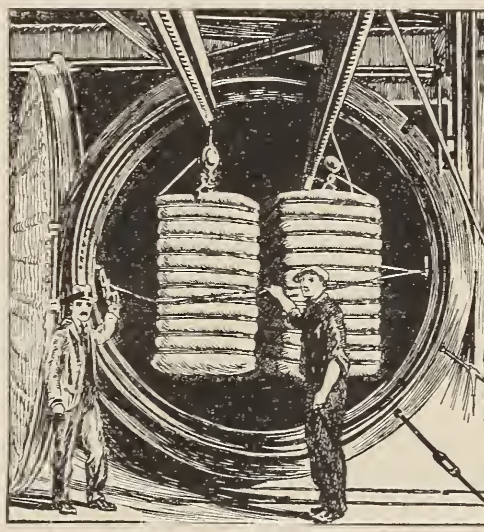
Nearly related to the grains are grasses. The United States has a forage crop (exclusive of corn stalks) of over 100,000,000 tons, valued at nearly $1,000,000,000. The best hay in the eastern part of the country comes from dried timothy grass and clover, the stems and leaves as well as the fruits forming the so-called hay. In some parts of the West a kind of clover called alfalfa is much grown, as it is adapted to the semi-arid conditions of that part of the country.



Cotton-producing regions.

**Cotton.** — Among our fruits cotton is probably that of the most importance to the outside world. The United States produces over three fourths of the world's cotton supply, and a large proportion of the crop is exported. Nearly 12,000,000 bales were raised in 1920.

The cotton plant is essentially a warmth-loving plant. Its commercial importance is gained because the seeds of the fruit have long filaments attached to them. Bunches of these filaments, after treatment, are easily twisted into threads from which are manufactured cotton cloth, muslin, calico, and cambric. In addition to the fiber, cottonseed oil, a substitute for olive oil, is made from the seeds, and the refuse makes an excellent fodder for cattle.

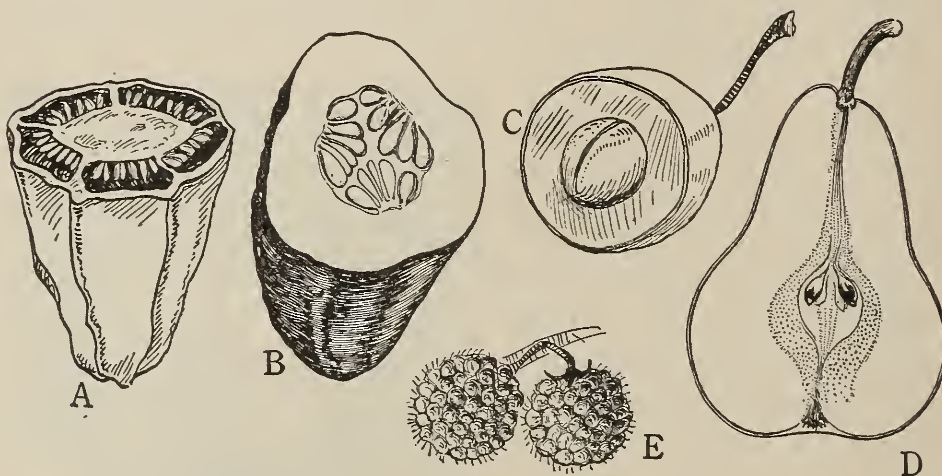


Chamber for fumigating imported bales of cotton at Boston, Massachusetts, to guard against the entry of the pink boll worm, another great pest.

**Cotton Boll Weevil.** — The cotton crop of the United States has been threatened rather recently with destruction by a beetle called the cotton boll weevil. This insect, introduced from Mexico in 1894, has now spread over almost the entire cotton-raising area of the South. It bores into the young pod of the cotton and develops there, stunting the growth of the fruit to such an extent that seeds may not be produced. The loss in Texas alone has been estimated at over $10,000,000 a year. This weevil, because of the protection offered by the cotton boll, is very difficult to exterminate. The weevils are destroyed by birds, the infected bolls and stalks are burned, millions are killed each winter by cold, they are the prey of other insects; but at the present time they are one of the greatest pests the South knows. The best method of fighting them seems to be planting the cotton early so that it will ripen before the boll weevil matures.

**Garden Fruits.** — Green fruits and vegetables have come to play an important part in the dietary of man. People in this country are beginning to find that more vegetables and less meat are better than the meat diet so often used.

Some of the most important fleshy fruits — squashes, cucumbers, pumpkins, and melons — are examples of the *pepo* (pē'pō) type of fruit; tomatoes and peppers are types of *berries* in botanical language, for a berry is any soft or juicy fruit con-




Various types of fruits: *A*, berry (pepper); *B*, pepo (cucumber); *C*, drupe or stone fruit (cherry); *D*, pome (pear); *E*, aggregate fruit made up of drupelets (raspberry).

taining small seeds. The so-called berries — strawberries, raspberries, and blackberries — of our gardens bring in an annual income of $25,000,000 to our fruit raisers. Beans and peas are important as foods because of their relatively large amount of protein. Canning green corn, peas, beans, and tomatoes has become an important business.

**Orchard and Other Fruits.** — In the United States over 175,000,000 bushels of apples are grown every year. Pears, plums, apricots, peaches, and nectarines also are raised in large orchards, especially in California. Nuts form one of our important articles of food, largely because of the great amount of protein contained in them.

The grape crop of the world is commercially valuable, because of the raisins and wine produced. Lemons, oranges, and grape-

fruit are of commercial value in this country as well as in other parts of the world. Figs, olives, and dates are staple foods in the Mediterranean countries and are sources of wealth to the people there, as are coconuts, bananas, and many other fruits in tropical countries.

**Beverages and Condiments.** — The coffee and cocoa "beans," both products of tropical regions, form the basis of two very important beverages of civilized man. Coffee is a stimulant, while cocoa and chocolate rank high in food value. Black and red pepper, mustard, allspice, nutmegs, cloves, and vanilla are all products of various fruits or seeds of tropical plants.

**Summary.** — This chapter has shown us that fruits hold seeds, that the destiny of the plant depends largely upon the adaptations which the plant has for scattering its seeds. Hence we find varied devices in fruits and seeds for getting the seeds placed as far as possible from the parent plant.

To man seeds and fruits have a commercial and economic value. Man's life on the earth may be said to depend largely upon his control over the cereal crops.

**Problem Questions.** — 1. What are the parts of a typical fruit?

2. Classify the adaptations in fruits for scattering seeds.

3. Classify devices in seeds for scattering.

4. Name five pairs of seeds and fruits which have the same method of dispersal.

5. Explain why three different weeds are so plentiful.

6. Make a classification of fruits, giving characteristics of each group.

7. Discuss the economic importance of five different crops in the United States.

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# VI. SEEDS AND SEEDLINGS

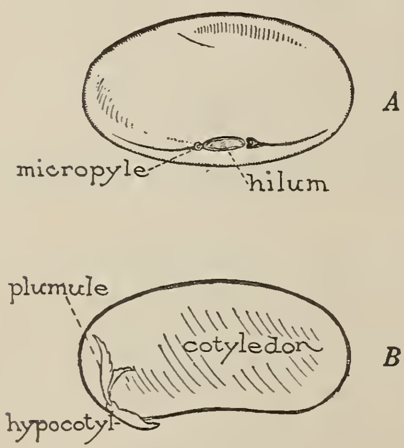
***Problem.*** *A study of seeds in their relation to the new plant. (Laboratory Manual, Prob. X; Laboratory Problems, Probs. 42 to 50.)*

(*a*) *The relation of the young plant to its food supply.*

(*b*) *How the young plant makes use of its food supply.*

**Relation of Flower to Fruit.** — We have already found in our study of the fruit that the bean pod is a direct outgrowth from the flower. *It is, in fact, the ovary of the flower, with the part immediately surrounding it, which has grown larger to make a fruit.*

**Use of Fruit.** — The fruit holds and protects the seeds until the time comes when they are able to germinate and produce new plants like the original plant from which they grew. Then, as we have seen, it may help to scatter them far and wide.



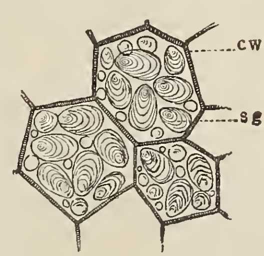

A bean seed: *A*, entire; *B*, after removing the testa or outer coat and one cotyledon.

**The Bean Seed.** — We have already been able to identify in the pod of the bean the style, stigma, and ovary of the flower. The opened pod discloses the seeds lying along one edge of the pod, each attached by a little stalk to the inner wall of the ovary. If we pull a single bean from its attachment, we find that the stalk leaves a scar on the coat of the bean; this scar is called the *hilum* (hī′lum). The tiny hole near the hilum is the *micropyle.* Turn back to the Figure (p. 26) showing the fertilization of an ovule. Find there the little hole through which the pollen tube reached the embryo sac. This hole or micropyle remains and is found in the seed. The thick outer coat, or

*testa,* is easily removed from a soaked bean; the delicate inner coat may escape notice. The part of the bean remaining seems to consist of two parts, which are called the *cotyledons* (kŏt-ĭ-lē′dunz); but if you separate them very carefully, you find the following structures between them. The rodlike part is called *hypocotyl* (hī-po-kŏt′ĭl, meaning *under the cotyledons*). This will later form the root and part of the stem of the young bean plant. The first true leaves, very tiny structures, are folded together between the cotyledons and are known as the *plu′mule* or *epicot′yl* (meaning *above the cotyledons*). The parts of the seed within the seed coats all together form the *embryo* or young plant. A bean seed contains, then, a tiny plant tucked away between the cotyledons and protected by a tough coat.

**Food in the Cotyledons.** — The problem now before us is to find out how the embryo of the bean is adapted to grow into an adult plant. Up to this stage of its existence it has had the advantage of food and protection from the parent plant. Now it must begin the battle of life alone. We shall find in all our work with plants and animals that the problem of food supply is always the most important problem to be solved by the growing organism. Let us see if this embryo is able to get a start in life (similar to that which many animals get in the egg) from food provided for it within its own body.

**Starch in the Bean.** — If we mash up a little piece of a bean cotyledon which has been previously soaked in water, and test for starch with iodine solution, the characteristic blue-black color appears, showing the presence of starch (p. 14). If a little of the stained material is mounted in water on a glass slide under the compound microscope, we find that the starch is contained in little ovoid bodies called *starch grains.* The starch grains and other food products are made use of by the growing plant.

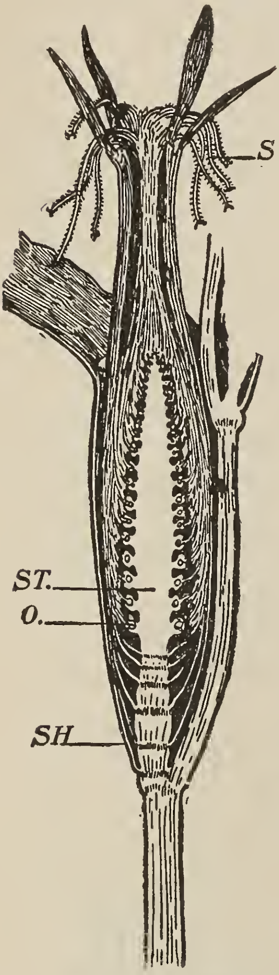


Starch grains in the cells of a bean: *cw,* cell wall; *sg,* starch grain.

Starches and sugars make up the great class of nutrients known as *carbohydrates.* Of these we shall learn more when we take up the study of foods. (The teacher may here refer to the chapter on Foods.)

**Protein in the Bean.** — Another nutrient present in the bean cotyledon is *protein*, as may be proved by a test with nitric acid and ammonium hydrate as directed on page 15.

The cotyledon contains not less than 23 per cent of protein, 57 per cent of carbohydrates, and about 2 per cent of fats.



Longitudinal section of young ear of corn: *O*, the fruits; *S*, the stigmas; *SH*, sheathlike leaves; *ST*, the flower stalk or peduncle. (After Sargent.)

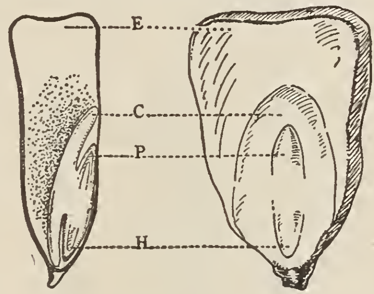
**Beans and Peas as Food for Man.** — The young plant within a pea or bean seed is well supplied with nourishment which it uses during its germinating, or until it is able to take care of itself. In this respect it is somewhat like a young animal within the egg, a bird or fish, for example. So much food is stored in leg′umes (as beans and peas are named) that man has come to consider them a very valuable and cheap source of food.

**Corn.** — The ear of corn is not a single fruit, but a large number of fruits in a cluster, like a bunch of bananas, for example. The husk of an ear of corn is simply a covering of leaflike parts which has grown over the young fruits for their better protection. The corncob is the much thickened flower stalk on which the flowers were clustered. The so-called *silk* of corn is nothing more than a long style and stigma. The corn grain itself was also part of the flower — the same part that formed the pod of the bean with its contained seeds. The corn grain is a complete fruit and not merely a seed.

**Structure of a Grain of Corn.** — Examination of a well-soaked grain of corn discloses a difference in the two flat sides of the grain. A light-colored area found on one surface marks the position of the embryo; the rest of the grain contains the food supply. The scar marking the former attachment of the silk is found near the outer edge of the grain.

A grain cut lengthwise perpendicular to the flat side and then dipped in weak iodine shows two distinct parts, an area containing considerable starch, the *en'dosperm*, and the embryo or young plant. Careful inspection shows the hypocotyl and plumule appearing as two points (the latter pointing up toward the free end of the grain) and a part surrounding them, the *single* cotyledon (see Figure). Here again we have an example of a fitting for future needs, for in this fruit the one seed has at hand all the food material necessary for rapid growth, although the food is stored outside the embryo.

**Endosperm the Food Supply of Corn.** — We do not find that the one cotyledon of the corn grain serves the same purpose to the young plant as do the two cotyledons of the bean. Although we find a little starch in the corn cotyledon, still it is evident from our tests that the endosperm is the chief source of food supply. The study of a thin section of the corn grain under the compound microscope shows us that the starch grains in the outer part of the endosperm are large and regular in size, while those near the edge of the cotyledon are much smaller and irregular, having large holes in them. We know that the germinating grain has a much sweeter taste than that which is not growing. This is noticed in sprouting barley or malt. We shall find later that, in order to make use of starchy food, a plant or animal must in some manner change it over into sugar. This change is necessary because starch cannot be absorbed by the young plant, while sugar can be.

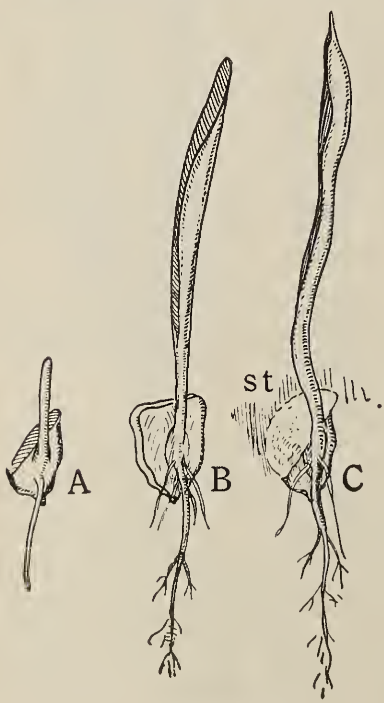


Grain of corn, in section and side view: *E*, endosperm; *C*, cotyledon; *P*, plumule; *H*, hypocotyl.

**Starch changed to Grape Sugar in the Corn.** — That starch is changed to grape sugar in the germinating corn grain can easily be shown in the following way. Cut lengthwise through the embryos of half a dozen grains of corn, place them in a test tube with some Fehling's solution, and heat to the boiling point. As no reaction occurs, no grape sugar is present in ungerminated

corn. Treat in the same way a half dozen grains of corn which have germinated, and they will give a brick red color showing the presence of sugar along the edge of the cotyledon and between it and the endosperm.

**Digestion.** — This change of starch to grape sugar in the corn is a process of *digestion.* Test a bit of unsweetened cracker (which we know contains starch) with Fehling's solution to show that no grape sugar is present. Chew some of the cracker a short time and notice that it will begin to taste sweet. Test the chewed cracker with Fehling's solution, and grape sugar will be found. Here again a process of digestion has taken place. Both in the corn and in the mouth, the change from starch to grape sugar is brought about by the action of peculiar substances known as digestive ferments, or *enzymes* (ĕn′zīmz), and the result is that substances which before digestion would not dissolve in water are now soluble.

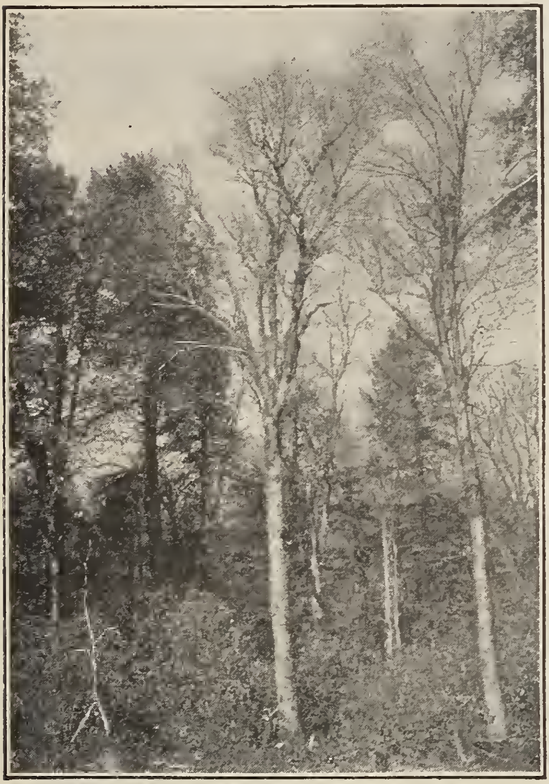



The use of the endosperm to corn: *A*, seedling with endosperm removed; *B*, normal seedling; *C*, seedling with starch *st* in place of endosperm.

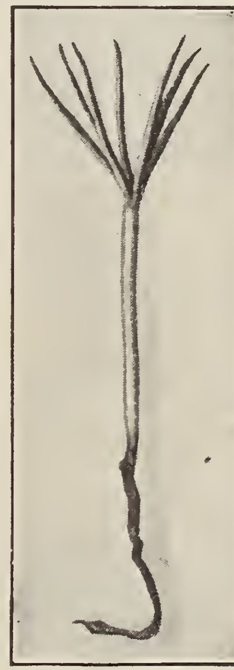
**The Action of Diastase on Starch.** — The enzyme found in the cotyledon of the corn, which changes starch to grape sugar, is called *di′astase.* It may be separated from the cotyledon and used in the form of a powder.

To a little starch in half a cup of water we add a very little (1 gram) diastase and put the vessel containing the mixture in a warm place, where the temperature will remain nearly constant at about 98° Fahrenheit. On testing part of the contents at the end of half an hour, we find that some of the starch has been changed to grape sugar. The next morning we find that the starch has been almost completely changed. Starch and warm water, under similar conditions will not react to the test for grape sugar.

**Suggested Experiment.** — Germinating corn grains, if deprived of their endosperm, soon die. But if the endosperm is removed and a little corn-starch paste is stuck to the embryo in place of the endosperm, the development will be but little affected (see Figure, p. 58). Evidently the enzyme formed in the cotyledon has the power to digest the starch paste, and the cotyledon transfers the digested food to the growing parts of the embryo.



A hardwood forest showing representative dicotyledonous trees.



A pine seedling. Note the number of cotyledons.

**Other Foods in Corn Grain.**—Other foods are present in the corn grain. A test for protein shows a considerable amount of this food. Oil also is found, and a small amount of mineral matter.

**Monocotyledons, Dicotyledons, and Polycotyledons.** — Plants that bear seeds having but a single cotyledon are called *mono-cotyle'dons*. Although we find many monocotyledonous plants in this part of the world, the group is characteristic of the tropics. Sugar cane and many of the large trees, such as the date palm, palmetto, and banana, are examples. Among the common mono-

cotyledons of the north temperate zone are corn, lily, grass, and asparagus.

*Dicotyle'dons*, or plants having two cotyledons in the seed, are those with which we come in contact most frequently in daily life. Many of our garden vegetables, peas, beans, squashes, melons, etc., all of our great hardwood forest trees, beech, oak, birch, chestnut, and hickory, used for the "trim" of houses, all of our fruit trees, pears, apples, peaches, and plums, and, in fact, a very large proportion of all plants living in the north temperate zone, are dicotyledons.

A third type of plant, with several cotyledons, is the group called the *polycotyle'dons*, represented by the pines and their kin. Such plants furnish most of the lumber and shingles used in the construction of frame houses. The soft woods (as the pines, hemlocks, spruces, and other "evergreens") are also of much value in the manufacture of paper. The wood-pulp industry has grown to such proportions as to be a menace to our softwood forests.

**Problem.** *A study of the factors necessary for awakening (germinating) the embryo within the seed. (Laboratory Manual, Prob. XI; Laboratory Problems, Probs. 33 to 37.)*

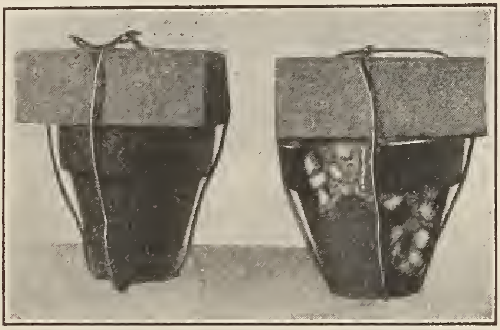
(*a*) *The part played by moisture.*
(*b*) *The function of temperature.*
(*c*) *The use of oxygen.*
(*d*) *The use of food.*

In making a series of experiments it is important to keep the conditions uniform, varying only the one we are testing.

**External Factors which determine the Growth of Seeds.** — We know that a dry seed, after lying dormant and apparently dead for months and sometimes for years, will, when the proper stimuli are applied to it, wake up and show signs of life. Something from outside the seed must evidently start the growth of the little embryo within the seed coats. There are several factors which are absolutely necessary for *germination*, as this beginning of growth is called.

**Water a Factor.** — We can prove that the bean seed will take up a considerable amount of water and that it swells during the process. Fill a flowerpot almost to the top with dry

beans, cover them securely as shown in the following illustration, and place the flowerpot in water overnight. The force exerted by the swelling seeds is sufficient to break the flowerpot. A dry seed will not germinate. The exact amount of water which is most favorable for the germination of a seed can be determined only by careful experiment. An oversupply of water will prevent growth of seeds almost as effectually as no water at all. In general the amount most favorable for germination is a moderate supply.



The expansive force of germinating seeds. The flowerpot to the left was filled with dry beans, a block of wood wired on, and the whole apparatus placed in a pail of water overnight. The result is shown at the right.

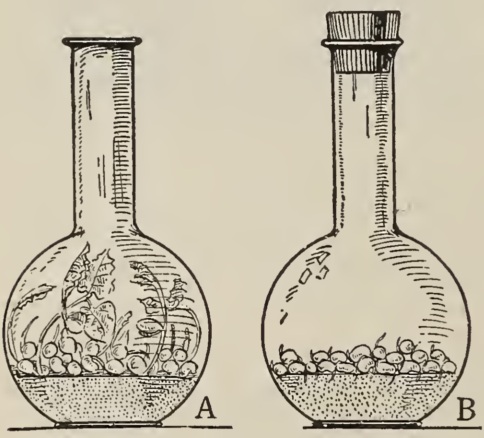
**Moderate Temperature is Best.** — Another factor influencing the germination of seeds is that of temperature. The temperature at which different varieties of seeds germinate varies greatly. As a general rule, increase in temperature is favorable

Effect of water upon the growth of trees. The trees were all planted at the same time in soil that is sandy and uniform. They are irrigated by a small stream running from left to right. Most of the water soaks in before reaching the last trees.

up to a certain point, beyond which it is injurious to the young plant, and seeds exposed to a moderate temperature do better in the long run than those in the heat.

Light has a certain marked effect on young seedlings, which will be considered when we take up the growth of the stem in more detail.

**Some Part of the Air a Factor.** — It is an easy matter to prove that peas or beans will not germinate without a supply of air. Equal numbers of soaked peas, placed in two flasks, one tightly stoppered, the other having no stopper, with identical conditions of light, temperature, and moisture, show that the seeds in both flasks start to germinate, but that those in the closed flask soon stop growing while the others continue to grow almost as well as similar seeds placed in an open dish.




Experiment to show that some part of the air is necessary for the germination of seeds. *A*, open flask; *B*, closed flask. A test of the air in *B* shows an excess of carbon dioxide; how do you account for this?

Why did not the seeds in the closed flask germinate? We have seen that to release the energy contained in a piece of coal it must be burned or oxidized. This requires a constant supply of fresh air containing oxygen. The seed, in order to release from its food supply the energy necessary for growth, requires oxygen, so that the oxidation of food may take place. *Hence a constant supply of fresh air is an important factor in germination.* It is necessary that air should penetrate between the grains of soil around a seed.

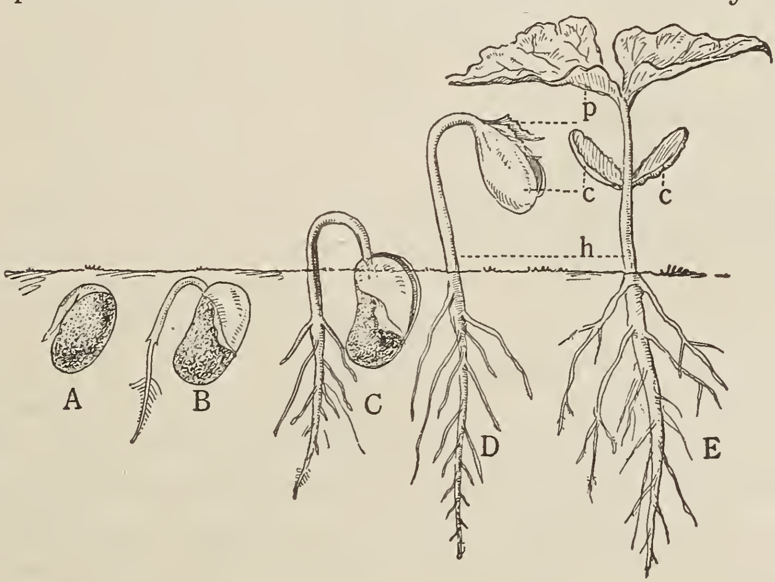
**Food oxidized in the Germinating Seed.** — But can it be proved that food substances are burned up during the germination of the seeds? The limewater test shows the presence of carbon dioxide in the closed flask. The carbon in the foodstuffs of the pea united with the oxygen of the air, forming carbon dioxide. Growth stopped as soon as the oxygen was exhausted.

The presence of carbon dioxide in the flask is an indication that a very important process which we associate with animals rather than plants, that of *respiration*, is taking place.

**Internal Factors Necessary for Germination.** — We have seen that stored food is found in the seed and is used by the embryo in getting a start in life. But to grow it is also necessary that the embryo be alive and that all parts be present. We speak of the vitality of a seed, meaning its ability to germinate. No matter how favorable the external conditions may be, no growth will take place unless the embryo is alive.

***Problem.*** *What becomes of the parts of the embryo during growth into a young plant?* (*Laboratory Manual, Prob. XII; Laboratory Problems, Prob. 25.*)

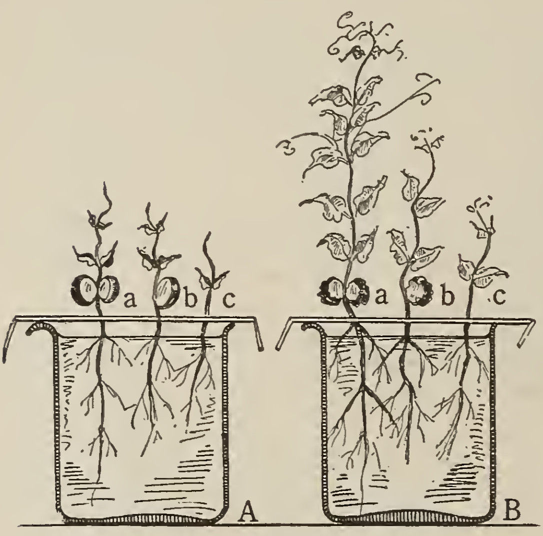
**Germination.** — If you plant a number of soaked kidney beans in damp soil or sawdust and at the end of each day remove




A series of early stages in the germination of a kidney bean. *A*, hypocotyl just appearing; *B*, hypocotyl curving downward; *C*, hypocotyl arched, pulling out the cotyledons; *D*, hypocotyl lifting cotyledons up, first true leaves appearing; *E*, cotyledons being used up, first true leaves expanded. *h*, hypocotyl; *c*, cotyledon; *p*, plumule.

one, you will be able to obtain a complete record of the growth of the kidney bean. The first signs of germination are the breaking of the testa and the pushing outward of the

hypocotyl to form the first root. A little later the hypocotyl begins to curve downward. An older stage shows the hypocotyl forming an arch and dragging the bulky cotyledons upward. The hypocotyl, as soon as it is released from the ground, straightens out, and the cotyledons are raised and opened. From between the cotyledons the budlike plumule or epicotyl grows upward, forming the true leaves and all of the stem above the cotyledons. As growth continues, we notice that the cotyledons become smaller and smaller, until eventually, their food contents having been absorbed into the young plant, they dry up and fall off. The young plant is now able to care for itself. *All the stages passed through by the young plant, from the time the seed begins to sprout until it can take care of itself by means of its roots and leaves, are known as the stages of germination.*



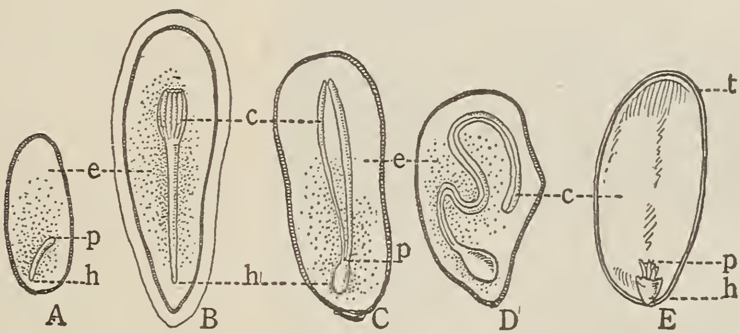

Experiment to show the function of the cotyledons of the pea: *a*, plant with both cotyledons, *b*, with one removed, *c*, with both removed. *A* at end of one week; ***B*** at end of three weeks.

In the pea, likewise, growth is at first made largely at the expense of the cotyledons, which never rise above ground. Removal of the cotyledons from a few germinating peas, and exposure of these peas to the same conditions as an equal number that are normal, show that the loss of the cotyledons retards growth and may result in the death of the seedlings.

**Seeds with Endosperm.** — In the seeds of the pea and bean we have found that the embryo takes up all the space within the seed coats. There are some dicotyledonous plants that have food stored outside of the embryo. Such a plant is the castor bean. A section cut vertically through the castor bean discloses a white oily mass directly under the seed coats. This mass is called the *endosperm.* If it is tested with iodine, it will be found

to contain starch; oil is also present in considerable quantity. Within the endosperm lies the embryo, a thin, whitish structure.

**The Uses of Seeds to the Plant.** — Not only does a seed serve to continue a species of plant in a certain locality, but it serves to give the plant a foothold in new places. Moving to a new home may be accomplished, as we shall see later, to a limited degree by cuttings, grafting, and in other ways, but the usual way is by the production and dispersal of seeds. Seeds blown by the wind, carried by animals, or distributed by a hundred




Arrangement of embryo in its relation to the endosperm: *A*, asparagus; *B*, pine; *C*, castor bean; *D*, morning glory; *E*, peanut. *c*, cotyledons; *e*, endosperm; *h*, hypocotyl; *p*, plumule; t, testa.

devices, work their way to pastures new, there to establish outposts of their kind.

Immense numbers of seeds are produced by a single plant. This is of great economic importance. A single pea plant may produce twenty pods, each containing from six to eight seeds. This would mean the possibility of nearly twenty-five thousand plants being produced from the original parent by the end of the second season and the rapid production of a source of food for mankind. A plant of Indian corn may yield over fifteen hundred grains of corn. On the other hand, many weeds produce seed in still greater numbers. A single capsule of Jimson weed has been found to hold over six hundred seeds. One milkweed may set free over two thousand seeds. The thistle is even more prolific.

Some seeds, especially those of weeds, are able to withstand great extremes of heat and cold and still to retain their ability

to germinate. Some have been known to retain their vitality for over fifty years. In plants, the seeds of which show unusual hardiness, it is found that the food supply is often so placed as to protect the delicate parts of the embryo from injury. The food is in a form not easily dissolved by water or broken up by the action of frost, so that it is kept in a hard state until a time when it is softened by the process of digestion during the growth of the plant. It can be seen that plants bearing seeds having some of the above characteristics have a great advantage over plants bearing seeds that are poorly protected.

Milkweed fruit, showing method of seed dispersal.

***Problem.*** *To study some methods of plant breeding.* (*Laboratory Manual, Prob. XIII; Laboratory Problems, Probs. 155 to 158.*)

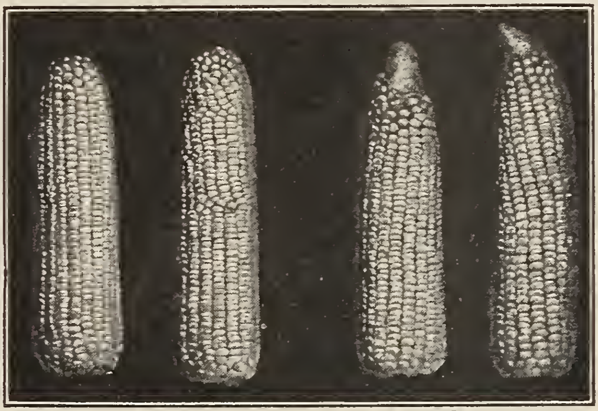
**Plant Breeding: Variation of Plants.** — Examination of a row of plants in a garden, of a hundred dandelion plants, or careful measurements made on the pupils in a classroom, would show us that no two plants and no two boys or girls have exactly the same measurements or characteristics. Each plant and animal tends to *vary* somewhat from its parent. This universal tendency among plants and animals is called the *law of variation.*

But a plant or animal hands down to its offspring the characteristics which it possesses, usually with only slight variations. Each one of us resembles our parents or our grandparents more closely than other persons, and far more closely than individuals of another race or species. Each plant produced from seed will

be in *most* respects like the plant which produced the seed. This is the *law of hered'ity.*

These two laws, of *variation* and of *heredity*, the basis on which Charles Darwin explained his theory of evolution, are made use of by plant and animal breeders. Since plants tend to vary and since such variations *may* be continued in their offspring, plant breeders have helped nature by artificially selecting and propagating the plants showing the characteristics wanted. In this way most of the varieties of our domesticated plants and animals have been developed.

**Selective Planting.** — *By selective planting we mean choosing the best plants and planting the seed from these plants with a view to improving the yield.* In doing this we select not necessarily the best fruits or grains, but the seeds from the *best plants.* A wheat plant should be selected not from its yield alone, but from its ability to stand disease and unfavorable conditions. By careful seed selection, some western farmers have increased their wheat production by 25 per cent. This, if kept up all over the United States, would mean over $250,000,000 a year in the pockets of the farmers.


*a* *b*
Improvement of corn by selection: *a*, improved type; *b*, original type from which it was developed.

Boys and girls who have gardens of their own can easily try experiments in selection with almost any garden vegetable. Corn is one of the best plants to experiment with. Gather for planting only the fullest ears and those with the largest kernels. You must also select from the plants those that produce the most ears. Plant these carefully selected corn grains in a plot by themselves in the garden, and compare their yield with that of the nonselected corn. The above picture shows what can be done by selection. Plants thus produced may become, by gradual

changes through many generations, new varieties of the original species from which they sprang.

**Hybridizing and Other Methods.** — We have already seen that pollen may be carried from one flower to another of the same species, and produce seeds. If pollen from one plant be placed on the pistil of another of an *allied* species or variety, fertilization may take place and new plants be eventually produced from the seeds. Such plants are called *hy'brids*.

Hybrids are extremely variable and often are apparently much unlike either parent plant. Such are some of the results of Luther Burbank's work with the hybrid plums, the Department of Agriculture experiments in the crossing of oranges and lemons, and the formation of thousands of new varieties of garden plants of various kinds — beans, peas, tomatoes, and the like. By far the greatest possibilities for the farmer or fruit grower seem to come from hybridizing.

Another method of obtaining new varieties of plants is that discovered by a Dutchman named Hugo de Vries. He found that a great variation might arise suddenly (instead of by gradual changes), thus producing a new variety which would at once breed true. Such a variation is called *mutation*, and the plant showing the new character is called a *mutant*. This law is of great value to breeders, as new plants or animals considerably unlike their parents may thus be formed and perpetuated. In 1862 a Mr. Fultz, of Pennsylvania, found three heads of beardless or bald wheat while passing through a large field of bearded wheat. He saved them, sowed them by themselves, and produced a quantity of wheat now known favorably all over the world as the Fultz wheat. The seedless orange is another example of a mutant.

Still more important is the discovery made by the monk Gregor Mendel. By experimenting with peas he found the laws under which certain characteristics are passed on to the descendants. Some of these *unit characters*, such as color of the pea, the shape of the pods, and smoothness of coat, always appear in certain proportions in the offspring, and some characters tend to disappear rather than others, when peas having different characters are cross bred. These facts have been so carefully worked out

that we know just what will happen if we cross breed certain plants having definite characteristics. It is to be expected that by a more extensive study of "Mendel's laws" plant breeders will be able to produce desired characters and to predict exactly what will happen as a result of cross breeding.

**Summary.** — We have found that within the seed a baby plant or embryo exists. Either packed around the embryo (as endosperm) or as a part of it (the cotyledons) is the food supply. When external conditions of temperature, moisture, and supply of oxygen are favorable, the embryo is awakened to activity and passes through the stages of germination.

We have seen also how the two factors of heredity and variation have produced new varieties of plants in the hands of scientific breeders.

**Problem Questions.** — 1. What are the chief differences between the bean and corn? Are they both seeds?

2. What is digestion? How is it brought about? Why is it necessary?

3. How are the forms of plants determined by their seeds?

4. What are the factors which influence germination? How do they do this?

5. What becomes of each part of a kidney bean after germination?

6. What are the uses of seeds to a plant? to man?

7. Discuss three factors in plant breeding.

### Problem and Project References

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U. S. Department of Agriculture, Various *Year Books* if available will give much good project material. Look over list of *Farmers Bulletins* for topics.

## VII. ROOTS AND THEIR WORK

***Problem.*** *A study of roots, to find out —*

*(a) Factors influencing direction of growth.*

*(b) Their structure.*

*(c) How they absorb soil water.*

*(Laboratory Manual, Prob. XIV; Laboratory Problems, Probs. 51 to 57.)*

The development of a bean seedling shows us that the root invariably grows first. *One of the most important functions of the root to a plant is that of a holdfast, an anchor to fasten it in the place where it is to develop.* In this chapter we shall find several other uses of the root to the plant: the taking in of water, with the mineral and organic matter dissolved therein, the storage of food, climbing, etc. But all functions other than the one first stated arise after the young plant has begun to develop.

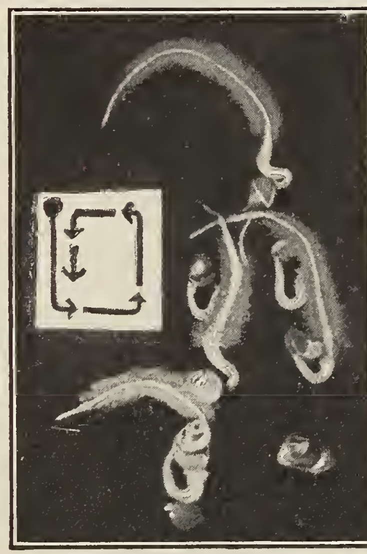
A root system, showing primary and secondary roots.

**Root System.** — If you dig up a young bean seedling and carefully wash the roots, you will see that a long root is developed as a continuation of the hypocotyl. This root is called the *primary* root. Roots growing from the primary are called *secondary,* and the roots growing from the latter are *tertiary* roots. The smallest branchings are called *rootlets.* Collectively all the roots and rootlets make up a *root system.*

**Downward Growth of Root. Influence of Gravity.** — Many of the roots examined take a more or less downward direction.

We are all familiar with the fact that the force called gravity influences life upon this earth to a great degree. Does gravity act on the growing root? This question may be answered by a simple experiment.

Plant mustard or radish seeds in a pocket garden,[1] stand it with the glass face vertical, and allow the seeds to germinate until the root has grown to a length of about half an inch. Then, keeping the glass face vertical, turn the pocket garden so that the roots will be horizontal, and allow it to remain for one day undisturbed. The tips of the roots now will be found to have turned in response to the change in position, and to point downward. This experiment seems to indicate that the roots are influenced to grow downward by the force called gravity.



Radish roots in a pocket garden that was turned four times in the direction of the arrow.

*The response of the plant* (*or any living thing*) *to gravity is called geotropism* (jē-ŏt′rō-pizm). *Roots are stimulated to grow downward; hence they are said to be positively geotropic* (jē-ō-trŏp′ik).

**Experiments to determine Influence of Moisture on a Growing Root.** — The roots in the pocket garden grow downward when all parts of the blotting paper are equally wet. That moisture has an influence on the growing root is easily proved.

Plant bird seed or the seed of mustard or radish in the underside of a sponge, which must be kept wet, and may be suspended by a string under a bell jar in the schoolroom window.

[1] *The Pocket Garden.* — A very convenient form of pocket germinator may be made in a few minutes in the following manner: Obtain two cleaned four by five negatives (window glass will do); place one flat on the table and on it place half a dozen pieces of colored blotting paper cut to a size a little smaller than the glass. Now cut four thin strips of wood so as to fit on the glass just outside of the paper. Next moisten the blotter, place on it some well-soaked radish or mustard seeds or grains of barley, and cover it with the other glass. The whole box thus made should be bound together with bicycle tape. Seeds will germinate in this box, and with care may live for two weeks or more.

Note whether the roots, when they reach the bottom of the sponge, continue to grow downward, or if the moisture in the sponge is sufficient to counterbalance the force of gravity and pull the roots to one side or upward.

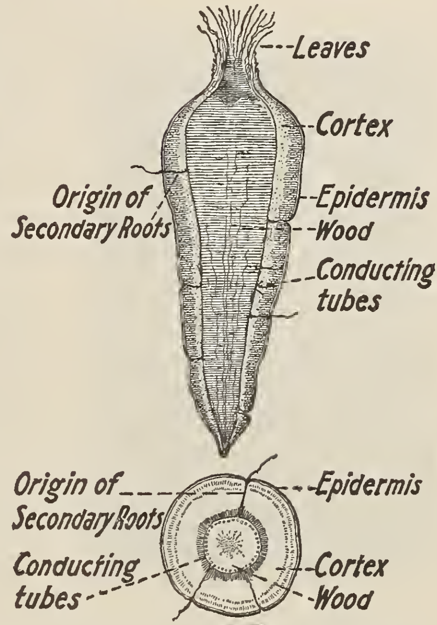
Another experiment is the following: Divide the interior of a shallow wooden box into two parts by a partition with an opening in it. Fill the box with sawdust. Plant peas and beans in the sawdust on one side of the partition, and water them very slightly, but keep the other side of the box well soaked. After two weeks, take up some of the seedlings and note the position of the roots.

**Water a Factor determining the Course taken by Roots.** — *Water, as well as the force of gravity, has much to do with the direction taken by roots.* Water is found below the surface of the ground, but sometimes at a great depth. In order to obtain a supply of water, the roots of plants frequently spread out very great distances. Most trees, and all grasses, have a greater area of surface exposed by the roots than by the branches. The mesquite bush, a low-growing tree of the American and Mexican deserts, often sends roots downward for a distance of forty feet after water. The roots of alfalfa, a clover-like plant used for hay in the western states, frequently penetrate the soil after water for a distance of ten to twenty feet below the surface of the ground.

Dandelion root. Notice its length.

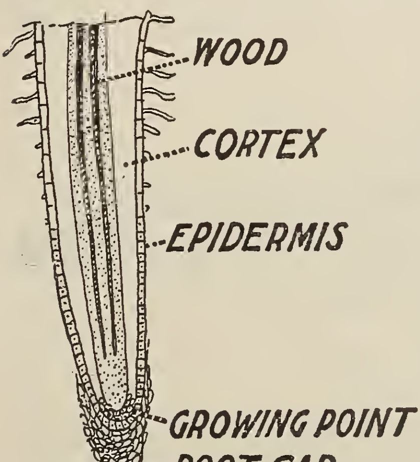
**Structure of a Taproot.** — To understand the structure of the root, it will be easiest for us to examine a large, fleshy one, so that we may get a little first-hand evidence as to its internal structure. A *taproot* is an enlarged primary root which stores food — such as a carrot or parsnip. It shows the chief parts in its composition clearly. If you cut open such a root and make a cross section of it, you find two distinct areas — an outer portion, the *cortex*, and an inner part, the *wood*. If you cut another root in lengthwise section, these structures show still

more plainly and an additional fact is seen; namely, that all the secondary roots leaving the main or primary root have a core of wood which bores its way out through the cortex wherever the rootlets are given off. The tubes which conduct the liquids up in a parsnip may be located by cutting off the tip of the root and placing the cut end in red ink for twenty-four hours. Sections of the parsnip will show the red ink in the wood and that it is most abundant in the outer region of the wood just within the cortex.




Lengthwise and cross sections of a taproot.

**Fine Structure of a Root.** — If we could now examine a much smaller and more delicate root in thin longitudinal section under the compound microscope, we should find the entire root to be made up of cells, the walls of which are rather thin.[1] Over the lower end of the root, where the growing tip is located, is found a collection of cells, most of which are dead, loosely arranged so as to form a *root cap*. This is evidently an adaptation which protects the young and actively growing cells just under the root cap, and as it is pointed, it assists in burrowing a hole through the earth. In the body of the root the *wood* can easily be distinguished from the surrounding *cortex*. The cells of the former have somewhat thicker walls. A series of tubelike structures may be found within the wood. These are made of cells




Lengthwise section of end of a growing root, much enlarged.

[1] Cross sections and longitudinal sections of tradescantia roots are excellent for demonstration of these structures.

which have grown together end to end, the long axis of the cells running the length of the main root. In their development these cells have lost their small ends, and now form continuous hollow tubes with rather strong walls. Other cells, which have developed greatly thickened walls, give mechanical support to the tubelike cells. *Collections of such tubes, some of which conduct fluids up and others conduct fluids down, and supporting woody cells together make up what are known as fibrovas'cular bundles.*


Young embryo of corn, showing root hairs (*R. H.*) and growing stem (*P.*).

**Root Hairs.** — Careful examination of the root of one of the seedlings of mustard, radish, or barley grown in the pocket garden shows a covering of very minute fuzzy structures which are at most an eighth or a sixth of an inch in length. They vary in length according to their position on the root, the longest root hairs being found near the point marked *R. H.* in the Figure, where they are most numerous also. These structures, called *root hairs*, are outgrowths of the outer layer of the root (the *epider'mis*), and are of very great importance to the living plant.

**Structure of a Root Hair.** — A single root hair examined under a compound microscope will be found to be a long, threadlike structure, almost colorless in appearance. The *cell wall,* which is very flexible and thin, is made up of *cel'lulose,* a substance somewhat like wood in chemical composition, through which fluids may easily pass.

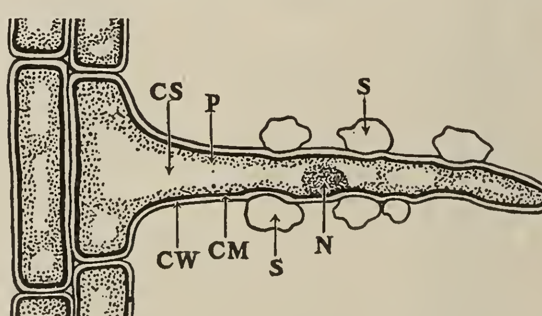
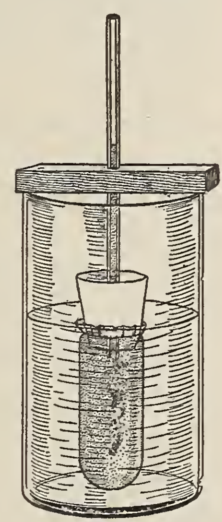



Diagram of a root hair: *CM*, cell membrane; *CS*, cell sap; *CW*, cell wall; *P*, cytoplasm; *N*, nucleus; *S*, soil particles.

If we had a very high power of the microscope focused upon

this cellulose wall, we should be able to find under it another structure, far more delicate than the cell wall. This is called the *cell membrane.* Clinging close beneath the cell membrane is the cytoplasm of the cell. The remaining space within the root hair is more or less filled with a fluid called *cell sap.* Forming a part of the living protoplasm of the root hair, sometimes in the hairlike prolongation and sometimes in that part of the cell which is in the epidermis of the root, is a *nucleus.* The cytoplasm, nucleus, and cell membrane are alive; all the rest of the root hair is dead material, formed by the activity of the living substance of the cell. *The root hair is part of a living plant cell* with a wall so delicate that water and mineral substances from the soil can pass through it into the interior of the root.

**How the Root absorbs Water.** — The process by which the root hair takes up soil water can better be understood if we make an artificial root hair large enough to be easily seen. This can be done in the following way: Pour some soft celloidin into a tube vial; carefully revolve the vial so that an even film of celloidin dries on the inside. Remove the film, fill with white of egg, and tie over the end of a rubber cork, through which a glass tube is inserted. When placed in water, the celloidin film gives a very accurate picture of the root hair at work. After a short time the liquid begins to rise in the tube, water having passed through the film of celloidin.



An artificial root hair, showing osmosis taking place.

**Osmosis.** — We have all noticed how a drop of red ink will spread through a glass of clear water. This is due to the process called *diffusion.* When two fluids of different density are separated by a membrane, diffusion will take place through it. This kind of diffusion is called *osmo'sis. By osmosis two gases or liquids of different density when separated by a membrane tend to pass through the membrane and mingle with each other; but the greater flow is always toward the fluid of greater density.* The method by which the root hairs take up soil water is osmosis.

**Passage of Soil Water in the Root.** — We have just seen that in an exchange of fluids by osmosis the greater flow is toward the denser fluid. Thus it is that the root hairs take in more fluid from the soil than they give to it. The cell sap, which partly fills the interior of the root hair, is a fluid of greater density than the water in the soil outside. When the root hairs become filled with water, the density of the cell sap is lessened, and the cells of the epidermis are thus in a position to pass along their supply of water to the cells next to them and nearer to the center of the root. These cells, in turn, become less dense than their inside neighbors, and so the transfer of water goes on by osmosis from cell to cell until the water at last reaches the inner wood. Here it is passed over to the tubes in the woody bundles and started up the stem. The pressure created by this process of osmosis is sufficient to send water up the stem to a distance, in some plants, of twenty-five to thirty feet. Cases are on record of water having been raised in the birch a distance of eighty-five feet.

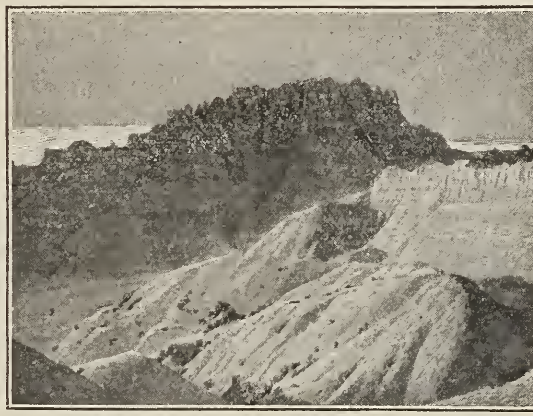
**Physiological Importance of Osmosis.** — It is not an exaggeration to say that osmosis is a process of vital importance not only to a plant, but to an animal as well. Foods are digested or changed into a soluble form in an animal so that they may pass through the walls of the food tube by osmosis and become part of the blood. Without the process of osmosis we should be unable to use much of the food we eat.

**Capillarity.** — The force known as *capillarity* (kăp-ĭ-lăr'ĭ-tĭ) also accounts for the rise of water in plants and helps it to pass through soil. If a number of small tubes of different bore be placed end down in a dish of water the water will be found to rise highest in the tube of smallest diameter, and least in the largest tube. This is brought about by the *adhesion* of the molecules of water to the glass. This force acts in the conducting tubes of plants as well as between the soil particles outside, and is a very probable factor in the transportation of water.

*Problem. A study of some of the relations between roots and the soil. (Laboratory Manual, Prob. XV, Laboratory Problems, Probs. 58 to 63.)*

(*a*) *Origin of soil.*
(*b*) *Kinds of soil.*
(*c*) *Water-retaining ability of soil.*
(*d*) *Fertility of soils.*
(*e*) *The relation between root hairs and soil.*
(*f*) *Root tubercles and crop rotation.*

**Composition of Soil.** — If we examine a mass of ordinary loam carefully, we find that it is composed of numerous particles of varying size and weight. Between these particles, if the soil is not caked and hard packed, we can find tiny spaces. In well-tilled soil these spaces are frequently formed and enlarged. They allow air and water to penetrate the soil. If we examine soil under the microscope, we find considerable water clinging to the soil particles and forming a delicate film around each particle. In this manner most of the water is held in the soil.



Inorganic soil is being formed by weathering.

Scientists who have made the composition of the earth a study, tell us that once upon a time at least a part of the earth was molten. Later, it cooled into solid rock. Soil making began when the ice and frost, alternating with heat, chipped off pieces of rock. These pieces in time became broken into fragments by action of ice, glaciers, running water, and the atmosphere. This process is called *weathering*. The action of the air is largely a process of oxidation. A glance at almost any crumbling stones will convince you of this, because of the yellow oxide of iron (rust) disclosed. By slow weathering the earth became covered with a coating of inorganic soil. Later, generation after generation of tiny plants and animals which lived in the soil died, and their remains formed the first organic materials of the soil. As time went on, living things of larger size paid their contribution to the organic soil.

You are all familiar with the difference between the so-called rich soil and poor soil. The dark or rich soil simply contains more material from dead plants and animals, and forms the portion called *humus*.

**Humus contains Organic Matter; Suggestions for Experiments.** — It is an easy matter to prove that black soil contains organic matter, for if equal weights of carefully dried humus and of soil from a sandy road are heated red-hot for some time and then reweighed, the humus will be found to have lost considerably in weight, and the sandy soil to have lost very little. The material left after heating is inorganic, the organic matter having been burned out and most of the products of combustion having been dissipated in the air.

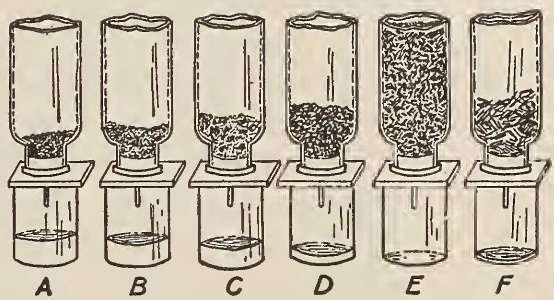
This picture shows how the forests help to cover the inorganic soil with an organic coating.

Organic soil holds water much more readily than inorganic soil, as a glance at the Figure on page 79 shows. If we fill the vessels with equal weights (say 100 grams each) of gravel, sand, barren soil, rich loam, and leaf mold, and 25 grams of dry, pulverized leaves, then pour equal amounts of water (100 c.c.) on each and measure all that runs through, the water that has been retained will represent the water supply that plants could draw on from such soils.

**The Root Hairs take more than Water out of the Soil.** — If a root containing a fringe of root hairs is washed carefully, it will be found to have little particles of soil still clinging to it. Examined under the microscope, these particles of soil seem to be cemented to the sticky surface of the root hair. The soil contains, besides a number of chemical compounds of various

mineral substances, — lime, potash, iron, silica, and many others, — a considerable amount of organic material. Acids of various kinds are present in the soil, — such as nitric acid, which comes from the dead bodies of plants and animals as they decay and oxidize, — and carbonic acid, formed by the union of the carbon dioxide from the roots and the water in the soil. These acids so act upon certain of the mineral substances that they become dissolved in the water which is afterward absorbed by the root hairs.

The proportion of each of these mineral materials is very small compared with the water in which they are found. A very great amount of water must be taken up by the roots in order that the plant may get the needed amount of mineral matter with which to build its protoplasm.



Experiment to illustrate the kind of soil which best retains water: *A*, gravel; *B*, sand; *C*, barren soil; *D*, rich soil; *E*, leaf mold; *F*, dry leaves.

Plants will not grow well without certain of these mineral substances. This can be proved by the growth of seedlings in a so-called nutrient solution. Such a solution contains all the mineral matter that a plant uses for food; but if certain ingredients are left out the plants placed in the solution will not live.

**Relation of Bacteria to Free Nitrogen.** — Plants and animals need the element nitrogen in order to make protoplasm within their own bodies. It has been known since the time of the Romans that the growth of clover, peas, beans, and other legumes in soil causes the ground to become more favorable for the growth of other plants. The reason for this has been discovered in late years. On the roots of the plants mentioned are found little swellings or nodules; and in each nodule exist millions of tiny organisms called *bacteria*, which take out nitrogen from the atmosphere and fix it so that it can be used by the plant; that is, they form *nitrates* (soluble compounds containing

nitrogen) which are useful to plants. Only these bacteria, of all living things, have the power to take the free nitrogen from the air and make it over into a form that can be absorbed by the roots. As all the compounds of nitrogen are used over and over again, first by plants, then as food for animals, eventually returning to the soil again, it is evident that any *new* supply of usable nitrogen must come by means of these nitrogen-fixing bacteria.

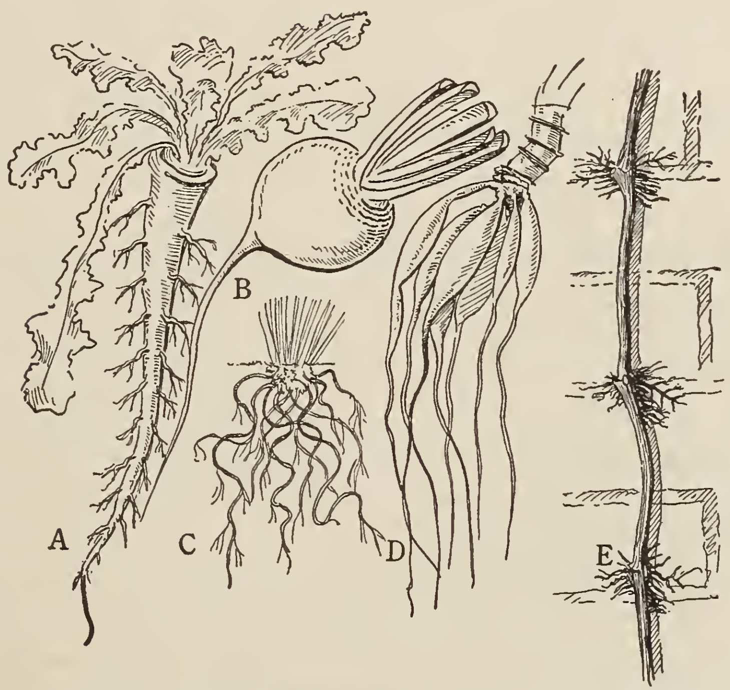
Tubercles on the roots of soy bean.

**Rotation of Crops.** — The facts mentioned above are made use of by intelligent farmers who wish to make as much as possible from a given area of ground in a given time. Such plants as are hosts for the nitrogen-fixing bacteria are planted early in the season. Later these plants are plowed in and a second crop is planted. The latter grows quickly and luxuriantly because of the nitrates left in the soil by the bacteria which lived with the first crop. For this reason, clover is often grown on land in which it is proposed to plant corn later, the nitrates left in the soil thus giving nourishment to the young corn plants. This alternation is known as rotation of crops. The annual yield of the average farm may be greatly increased by this means.

**Soil Exhaustion may be Prevented.** — Besides the rotation of crops, other methods are used by the farmer to prevent the exhaustion of raw food material from the soil. One method known as *fallowing* is to allow the soil to remain idle until bacteria and oxidation have renewed the chemical materials used by the plants. This is an expensive method, if land is dear. The more common method of enriching soil is by means of fertilizers, or material rich in plant food. Manure is most frequently used, but many artificial fertilizers, most of which contain nitrogen, are used, because they can be more easily transported and sold. Such are ground bone, guano (bird manure), nitrate of potash, and many others. Most fertilizers contain,

in addition to nitrogen, other important raw food materials for plants, especially potash and phosphoric acid.

**Roots help the Plant to Breathe.** — Although we shall find that leaves are the chief breathing organs of a plant, yet roots absorb much oxygen from the soil or the water into which they reach. The rows of dead trees around a pond that has been




Various forms of roots: *A*, taproot (dandelion); *B*, fleshy root (beet); *C*, fibrous root (crowfoot); *D*, fascicled root (dahlia); *E*, adventitious roots (English ivy, on a wall).

raised by damming indicates that one cause of the death of these trees was lack of oxygen. They were actually drowned.

The so-called "cypress knees," projections of the roots from cypress trees, are adaptations to obtain oxygen.

**Food Storage in Roots and its Economic Importance.** — The use the plant makes of the food stored in the root may be understood if we take up the life history of the parsnip. Such a plant is called a *bien'nial* because it produces no seed until the second year of its existence, after which it dies. Its growth the first summer forms the root we use as food. The food

stored in its root enables it to get an early start in the spring, so as to be better able to produce seeds when the time comes. Such plants live only under rather cool climatic conditions. Examples of other roots which store food are carrot, radish, yam, and sweet potato. This food storage in roots is of much practical value to mankind. Many of our most common garden vegetables, as those mentioned above and the beet, turnip, oyster plant, and others, are of value because of the food stored in roots. The sugar beet has, in Europe especially, become the basis of a great industry, producing in normal times over 40 % of the world's sugar supply. The products from other roots are used for medicine, as, for example, licorice, rhubarb, mandrake, ginger, and asafet′ida.

**Modified Roots.** — Although roots are primarily anchoring and absorbing organs they may, as we have seen, be used for food storage as well. Usually roots grow as a continuation of the hypocotyl of the seedling, but they may appear in unusual places on the stem or even from the leaves. Such roots are called *adventitious*. The clinging roots developed from the stem of English ivy, the stem roots of quick grass and the prop roots of Indian corn are examples.

Other unusual types of roots are the air roots of the tropical forests. Here plants called *epiphytes* or air plants live on tree trunks and obtain moisture from the nearly saturated air. Still other plants, like the mistletoe, actually strike their roots into the tissues of other plants and take their nourishment from them. Such plants are called *parasites* because they take their nourishment directly from other living organisms.

**Summary.** — We have found from a study of this chapter that roots are very sensitive to the force of gravity and that they have become modified for many purposes, as climbing, props, or food storage. The principal uses of the root to the plant are:

(1) They serve to hold the plant firmly in the ground.

(2) They serve to store food.

(3) They absorb mineral matter and water and transmit them to the rest of the plant.

(4) They help as breathing organs.

**Problem Questions.** — 1. What is geotropism? How does it act on roots?

2. What other factors influence the growth of roots?

3. What are root hairs and what is their function?

4. Explain osmosis.

5. How are roots able to take out mineral matter from the soil?

6. What are nitrogen-fixing bacteria? How do they do their work?

7. What proof have we that roots breathe?

8. Name some forms of modified roots and show their uses to the plant.

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# VIII. THE STRUCTURE AND WORK OF THE STEM

**Problem.** *To learn something of the structure and work of stems. (Laboratory Manual, Prob. XVII; Laboratory Problems, Probs. 75 to 78.)*

*(a) External structure of a dicotyledonous stem (optional).*

*(b) Internal structure of a dicotyledonous stem.*

*(c) Circulation in stems.*

*(d) Condition of food passing through the stem.*

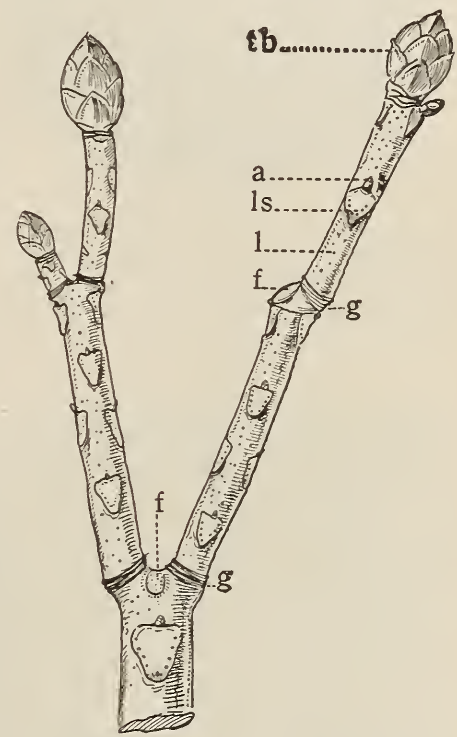
A bud is said to be "the promise of a branch." Any

A larch, an excurrent tree (at right), and an elm, a deliquescent tree (at left). Photographed by W. C. Barbour.

twig in winter shows not only the terminal bud, from which next season's continuation of the branch will come, but it also shows lateral buds placed just above the *leaf scars* which mark where last year's leaves were attached. The position of the most active buds determines the form of the future tree. If the terminal buds

grow more rapidly than those on the sides, we have a straight, tall, *excurrent* tree with one main trunk. Such are Lombardy poplars, pines, and cedars. If on the other hand the lateral buds grow faster than the terminal, we have a lower, spreading form of tree, as the elm or oak. Such a tree is called *deliquescent* (dĕl-ĭ-kwĕs′ent) in its method of growth.

**The External Structure of a Dicotyledonous Stem.** — A horse-chestnut twig in its winter condition shows the structure and position of the buds very plainly. When the twig grew last year the scales which covered the outside of the terminal bud dropped off, and the young shoot developed from the opened bud. The scales which dropped off left marks forming a little ring upon the bark of the twig. These rings, collectively named the *bud scars*, enable one to tell the age of the branch.

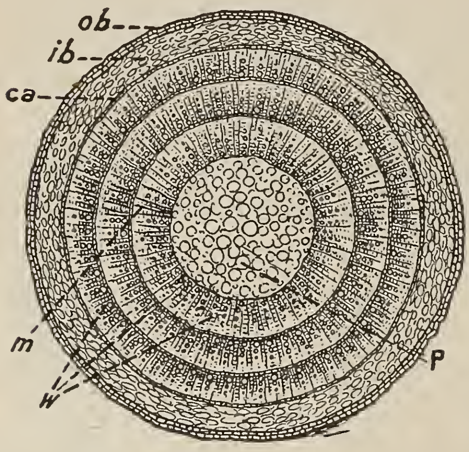



Horse-chestnut twig: *tb*, terminal bud; *a*, lateral bud; *ls*, leaf scar; *l*, lenticel; *f*, flower scar; *g*, bud scar. How many years old is this twig? How can you tell?

Just below the lateral buds are marks, known as *leaf scars*, that show the points at which leaves were attached. A careful inspection of the leaf scars reveals certain tiny dotlike traces arranged more or less in the form of a horseshoe. These traces mark the continuations of the same fibrovascular bundles which pass from the root up through the stem and out into the leaves, where we see them as the veins which act as the support of the soft green tissues of the leaf. *The most important use to the plant of the fibrovascular bundles is the conduction of fluids from the roots to the leaves and from the leaves to the stem and root.*

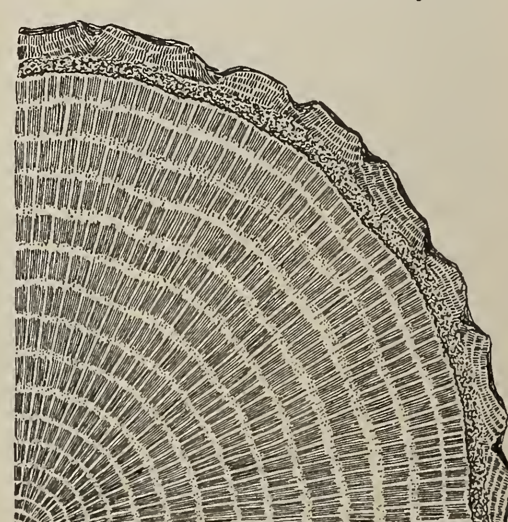
**Lenticels and their Uses.** — The tiny scars, which look like

little cracks in the bark, are very important organs, especially during the winter season, for they are the breathing holes of the tree. A tree is alive in winter, although it is much less active than in the warm weather. But all the year round oxygen is taken in and carbon dioxide given off through the *lenticels* (lĕn′tĭ-sĕlz), as the breathing holes in the trunk and branches of a tree are called.




Cross section of a three-year-old box elder: *ob*, outer bark; *ib*, inner bark; *ca*, cambium layer; *w*, three rings of wood; *m*, medullary ray; *p*, pith.

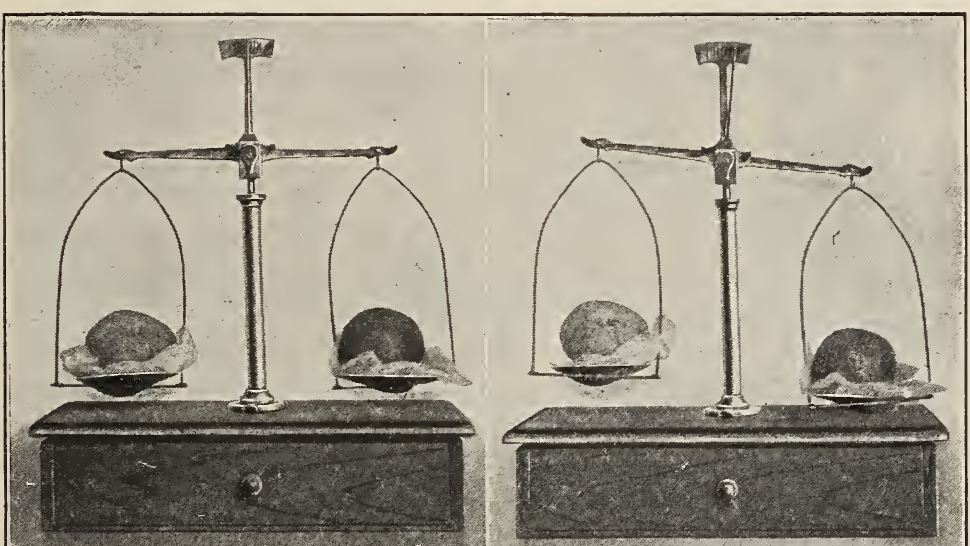
**A Dicotyledonous Stem in Cross Section.** — If we cut a cross section through a young horse-chestnut stem, we find it shows three distinct regions. The center is occupied by the spongy, soft *pith;* surrounding this is found the rather tough *wood,* while the outermost area is called *cortex* or *bark.* More careful study of the bark reveals the presence of three layers — an outer layer, a middle green layer, and an inner fibrous layer. This inner layer is made up largely of tough fiberlike cells known as *bast* fibers. The most important parts of this inner bark, so far as the plant is concerned, are *sieve tubes,* made by joining, end to end, long cells having perforated ends. Through these tubes, passing from cell to cell through the sievelike ends, food materials move downward from the upper part of



Quarter section of oak. Comparing this with the preceding picture, point out the bark, the cambium layer, the rings of wood, and the medullary rays.

the plant, where they are manufactured, to the stem and roots.

In the wood will be noticed (see Figures opposite) many lines radiating outward from the pith toward the cortex. These are the so-called med'ullary rays, thin plates of pith which separate the wood into a number of wedge-shaped masses. These masses of wood are composed of many elongated cells, which, placed end to end, form thousands of little tubes connecting the leaves with the roots. In addition to these are many thick-walled cells, which give strength to the mass of wood. In sections of wood which have taken several years to grow, we find so-called *annual rings.* The distance between one ring and the next (see first Figure on page 86) usually represents the amount of growth in one year. Growth takes place from an actively dividing layer of cells, known as the *cam'bium layer,* which is located between the wood and the bark; it forms wood cells from its inner surface and bark from its outer surface. Thus new wood is formed as a distinct ring around the old wood.

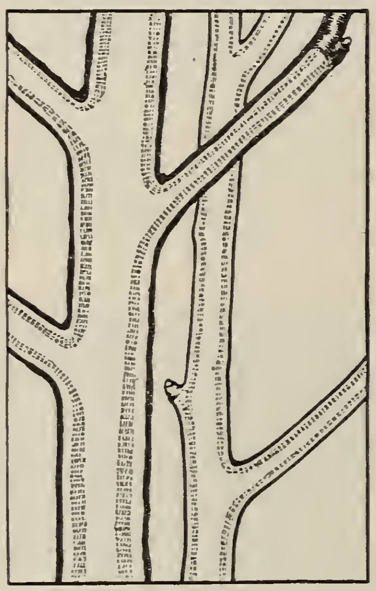


Experiment to show that the skin of the potato (a stem) retards evaporation.

**Use of the Outer Bark.** — The outer bark of a tree is protective. The cells are dead, the heavy woody skeletons serving to keep out cold, as well as to prevent the evaporation of

liquids from within. Most trees are provided with a layer of corky cells. This layer in the cork oak is thick enough to be of commercial importance. The function of the corky layer in preventing evaporation is easily demonstrated by the potato, which is a true stem, though found underground. If two potatoes of equal weight are balanced on the scales, the skin having been peeled from one, the peeled potato will be found to lose weight rapidly. This is due to loss of water, which is held in by the skin of the unpeeled potato. (Figure on page 87.)

**Passage of Fluids up and down the Stem.** — If any young growing shoot (young seedling of corn or pea, or the older stem of garden balsam, touch-me-not, or sunflower) or an apple twig is placed in red ink (eosin), left in the sun for a few hours, and then examined, the red ink will be found to have passed up the stem in the woody tubes immediately under the inner bark. These woody tubes make up the inner portion of the fibro-vascular bundles called the wood or *xylem* (zī′lĕm).

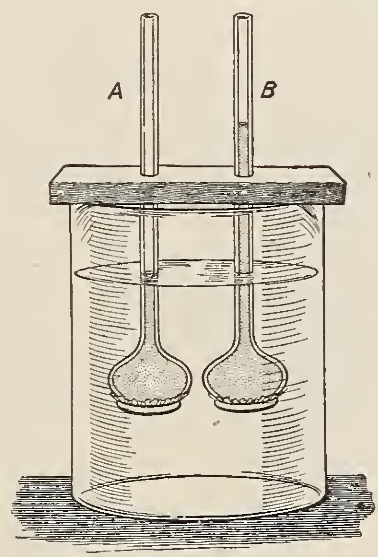


Apple twigs split to show the course of colored water (the dark lines just inside the bark) up the stem.

If willow twigs are placed in water, roots soon begin to develop from that part of the stem which is under water. If now the stem is girdled by removing the bark in a ring just above where the roots are growing, the part of the stem below the girdled area will eventually die, and new roots will appear above it. The food material necessary for the outgrowth of roots evidently comes from above; in fact it moves in a downward direction just outside the wood in the layer of bark which contains the bast fibers and sieve tubes. These sieve tubes make up the outer portion of the fibrovascular bundles which is called *phloem* (flō′ĕm). Food substances are also conducted to a much less extent in the wood itself, and food passes from the inner bark to the center of the tree by

way of the pith plates or medullary rays. It is found that much starch is stored in this part of the tree trunk. The experiment with the willow explains why it is that trees die when girdled so as to cut the sieve tubes of the inner bark. The food supply is cut off from the protoplasm of the cells in the part of the tree below the cut area. Many of the canoe birches of our Adirondack forest are thus killed, girdled by thoughtless visitors.

**In What Form does Food pass through the Stem?** — We have already seen that materials in solution (those substances which will dissolve in water) will pass from cell to cell by the process of osmosis. This is easily shown in the following experiment (see Figure). Two thistle tubes are partly filled, one with starch and water, the other with sugar and water, and a piece of parchment paper is tied over the lower end of each. The lower ends of both tubes are placed in a glass dish under water. After twenty-four hours, the water in the dish is tested for starch, and then for sugar. We find that only the sugar, which has been dissolved by the water, can pass through the membrane.



Experiment showing the non-osmosis of starch and water (tube *A*), and osmosis of sugar solution (tube *B*).

**Digestion.** — As we shall see later, the food for a plant is manufactured in the leaves or in the stems, etc., wherever green coloring matter is found. Much of this food is in the form of starch. But starch, being insoluble, cannot be passed from cell to cell in a plant. It must be changed to a soluble form. This process of digestion seemingly may take place in all living parts of the plant, although most of it is done in the leaves. In the bodies of all animals, including man, starchy foods are changed in a similar manner, but by different digestive ferments, into a soluble form, grape sugar.

The food material may be passed in a soluble form until it comes to a place where food storage is to take place, then it can be transformed to an insoluble form (starch, for example); later, when needed by the plant in growth, it may again be transformed and sent in a soluble form through the stem to the place where it will be used.

**Building of Proteins.** — Another very important food substance stored in the stem is *protein.* Of the building of protein, little is known. We know it is an extremely complex chemical substance which is made in plants from compounds containing nitrogen, as the nitrates and compounds of ammonia received through the roots from the organic matter contained in the soil, and combined with sugar or starches in the body of the plant.

Some forms of protein substance are soluble and others insoluble in water. White of egg, for example, is very slightly soluble, but can be rendered insoluble by heating it until it coagulates. Insoluble proteins are digested within the plant; how and where is but slightly understood. Soluble proteins pass down the sieve tubes in the bast and then may be stored in the bast, or they may pass into the root, fruit, or seeds of a plant, and be stored there.

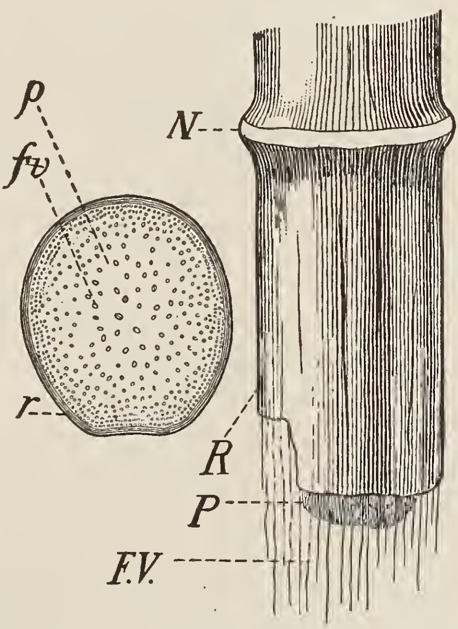
Diagram to show the areas in a plant through which raw food materials pass up the stem (wavy line in diagram) and food materials pass down (even line in diagram). (After Stevens.)

**What forces Water up the Stem.** — We have seen that the process of osmosis is responsible for taking in soil water, and that the great extent of the absorbing surface exposed by the root hairs makes possible the absorption of a large amount of water. Frequently this is more than the weight of the plant every twenty-four hours.

Experiments have been made which show that this water is in some way forced up the tiny tubes of the stem. During the spring season, in young and rapidly growing trees, water has been proved to rise to a height of nearly ninety feet.

*Root pressure* is the force with which soil water passes from the roots into the stem. This flow of water is the result of osmosis in the root hairs and later in the cells of the root. But root pressure alone cannot account for the rise of sap (water containing materials taken out of the soil) to a height of several hundred feet, as in the stems of the big trees of California. Other factors that are believed to be at work are the cohesion of particles in tiny columns of water, and osmosis between living cells that lie along the course of the woody bundles of long narrow dead cells that form the ducts. But no complete and adequate explanation has been found for the rise of sap to great heights.

A very great factor, however, is one which will be more fully explained when we study the work of the leaf. Leaves pass off an immense quantity of water by evaporation, and this process seems to result in a kind of suction on the tiny columns of water in the stem. In the fall, after the leaves have gone, much less water is taken in by roots, showing that an intimate relation exists between the leaves and the root.

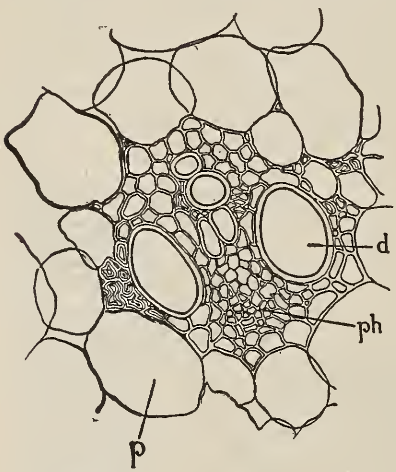



A broken cornstalk, with cross section (at left): *N*, node; *R*, *r*, rind; *P*, *p*, pith; *FV*, *fv*, fibrovascular bundle.

**Structure of a Monocotyledonous Stem.** — A piece of cornstalk examined carefully in cross and longitudinal section shows us that the main bulk of the stalk is made up of pith, through which are scattered numerous stringy, tough structures called *fibrovascular bundles.* The latter are the woody bundles of tubes which in this stem pass through the pith and run into the leaves, where (in young specimens) they may be followed as veins. The outside of the corn stem is formed of large numbers of fibrovascular bundles, which, closely packed together, form a hard, tough outer *rind.* Thus the woody material on

the outside gives mechanical support to an otherwise spongy stem.

**Structure of a Fibrovascular Bundle in a Monocotyledonous Stem.** — A cross section of a fibrovascular bundle under the microscope shows a collection of supporting cells and ducts without any cambium layer. Woody cells with thick walls serve to support the bundles of tubes. Some, called *sieve tubes,* are developed to carry food downward from the leaves, while others (see Figure) carry water and air upward. The bundles elongate rapidly, but are limited in their growth outward by the hard-walled, woody cells (the xylem). An old stem of a monocotyledon contains more bundles than does a young stem, the bundles growing out as veins into the leaves.




Cross section of monocotyledonous fibrovascular bundle, much magnified: *ph*, sieve tubes in which food passes down; *d*, woody portion or bundle ducts which carry air and water upward; *p*, pith cell.

**Comparison in the Growth of a Dicotyledonous and a Monocotyledonous Stem.** — In the dicotyledonous stem the woody bundles appear in a ring. They are open and grow in both directions, inward and outward, from that part of the bundle called the cambium. This layer in older stems soon becomes a complete ring around the tree. On the outside of the cambium layer is found the phloem, or portion containing the sieve tubes which bear elaborated food toward the roots. On the inside is found the xylem or woody tubes that carry water and air upward.

In the monocotyledonous stem the bundles are scattered, lack the cambium, and increase in number as the stem grows older. They contain sieve tubes on the inside and water and air bearing tubes in their outer part.

**Food Storage.** — Many monocotyledonous trees which live for long periods of time store food in large quantities in the trunk. The sago palm is an example. The sugar cane is a monocotyledonous stem of great commercial value because of the sugar

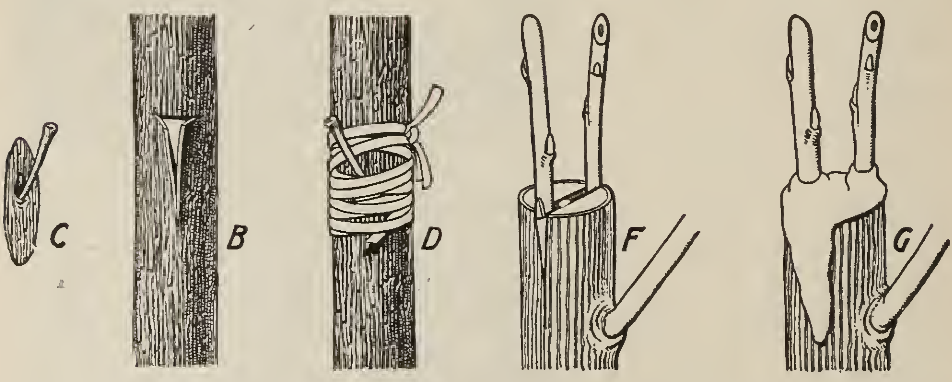
contained in its sap. Over 70 pounds of sugar on the average is used annually by each person in the United States. Most of the cane sugar grown in this country comes from Louisiana and Texas, although these states do not begin to supply the needs of this country.

Palm, tapped at the top for its sweet sap, from which a drink is made in tropical countries.

Various types of stems form some of the most important sources of man's food supply. Our common potato, celery, onions, rhubarb, asparagus, and Jerusalem artichoke are well-known examples. The sago palm is the chief support of many of the natives of Africa. An adult tree will furnish 700 pounds of sago meal, $2\frac{1}{2}$ pounds being enough to support a man one day. Maple sugar is a well-known commodity which is obtained by boiling the sap of the sugar maple until it crystallizes. Over 16,000 tons of maple sugar is obtained every spring, Vermont producing about 40 per cent of the total output.

**Budding.** — We have said a bud is a promise of a branch; it may be more, the promise of a new tree. If the owner of an apple or peach tree wishes to vary the quality of fruit borne by the tree, he may in the early fall cut a T-shaped incision in the bark and then insert a bud surrounded with a little bark from the tree of the same species bearing the desired fruit. The

bud is bound in place and left over the winter. When a shoot from the embedded bud grows out the following spring, it is found to have all the characteristics of the tree from which it was taken. This process is known as *budding*.




Budding (*CBD*) and grafting (*FG*): *C*, shield-shaped bud from desired variety; *B*, T-shaped incision, ready to receive the bud; *D*, bud inserted and bound in place. *F*, two grafts from desired variety in place in split end of trunk; *G*, same after application of grafting wax to hold them in place.

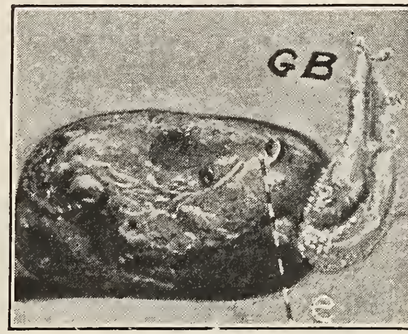
**Grafting.** — Of much the same nature is grafting. Here, however, a small portion of the stem of the closely allied tree is fastened into the trunk of the growing tree in such a manner that the two cut cambium layers will coincide. This will allow the passage of food into the grafted part and insure the ultimate growth of the twig. Grafting and budding are of considerable economic value to the fruit grower, as they enable him to produce at will trees bearing choice varieties of fruit.[1]

In both of the above processes, the secret of successful growth lies in the fact that the cambium surface of the bud or the graft comes in contact with the cambium of the tree to which it is applied, thus putting it in direct communication with a supply of food from the tree which is already established.

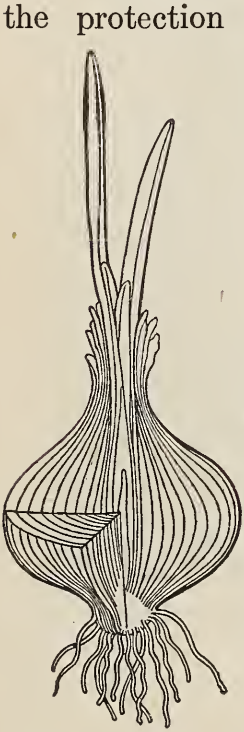
**Modified Stems.** — We have already seen that the factors of the environment, light, heat, gravity, moisture, air currents and other factors, act upon the living substance of plants, causing them to react in various ways. The changes which take place usually fit the plant to succeed better in its battle for life.

[1] For full directions for budding and grafting, see Goff and Mayne, *First Principles of Agriculture*, Chap. XIX, or Hodge, *Nature Study and Life*, pages 169–179.

Thus various modifications of stems have been brought about. Some stems, like the sago palm and potato, become storehouses of food. The potato tuber is simply a much thickened storage stem, as one may easily prove by examination of the so-called "eyes" of a sprouting potato. The tiny projection growing within the eye is a bud, which may give rise to a branch later. Food and water are stored within the tuber. Some stems have come to exist underground because of the protection thus afforded. The pest called couch grass or quick grass has such a stem. Bulbs, like the onion or lily, are examples of stems which have become shortened and covered with thickened leaves, filled with food. Still other stems, like that of the dandelion, have become reduced in length, which prevents them from being broken off by grazing animals. Climbing stems, as a result of the stimulation of the sun, twist around a support in a given direction, some revolving with and some against the course of the sun.



The potato tuber is a stem; note the branches *GB* growing from the "eyes" at one end. At *e* is another "eye."

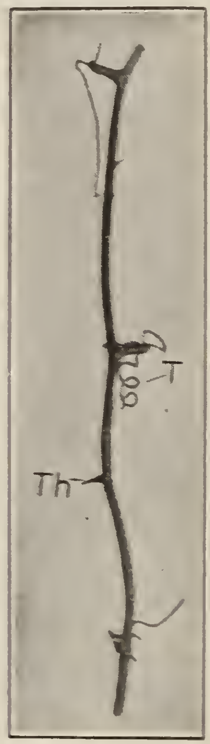

Cross and longitudinal section of onion.

We also find stems and leaves modified to become holdfasts for the plant. Such are the tendrils found in climbing plants. Thorns, a protection from animals, may be modified parts of leaves or of stems, depending upon where they come out on the stem. (See pictures on the following page.)

**Summary.** — A stem is a developed bud, the form of the plant depending upon the placing of the actively growing buds in the young plant. Dicotyledonous and monocotyledonous stems differ in structure, as summarized on page 92.

Stems are seen to act as organs to hold the leaves in a favorable position so as to secure sunlight. They store food for the plant and they act as organs to carry soil water and gases from the roots to the leaves and to carry elaborated food from the leaves to other parts of the plant.

**Problem Questions.** — 1. Name all the adaptations found in some bud. Give the specific purpose of each adaptation.



Catbrier; the tendrils *T* are modified stipules (parts of leaves); *Th*, thorn.


A honey locust; the thorns in this case are modified branches (page 95).

2. How do stems help in breathing?

3. Compare a dicotyledonous and a monocotyledonous stem
   (*a*) in method of growth;
   (*b*) in microscopic cross section.

4. How may insoluble food be made use of by a plant? Explain.

5. Compare budding and grafting as methods of propagation.
6. Discuss modifications in stems.
7. Name ten products obtained from stems.

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## IX. LEAVES AND THEIR WORK

**Problem.** *A study of leaves in relation to their environment, to show —*

(*a*) *Reactions of stems and leaves to light.*

(*b*) *Structure.*

(*c*) *Important functions.*

(1) *Food-making and its by-product.*

(2) *Evaporation of excess water.*

(3) *The leaf as a mill* (*optional*).

(4) *Absorption and respiration.*

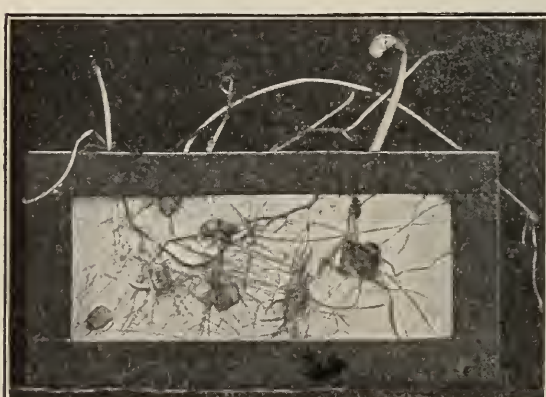
(*d*) *Means of protection* (*optional*).

(*e*) *Some leaf modifications* (*optional*).

(*f*) *Importance to man.*

(*Laboratory Manual, Prob. XVIII; Laboratory Problems, Probs. 65 to 74.*)

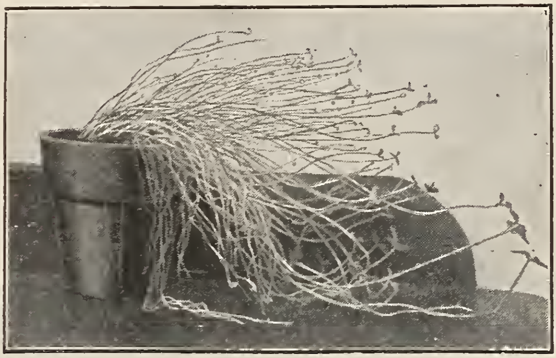
**Differences between Roots and Stems.** — A comparison of the young root and the developing stem of a bean seedling shows that several marked differences exist: (1) the color of the stem is greenish, while the roots are gray or whitish; (2) the stem has leaves and branches leaving it in a more or less regular manner, while the smaller roots are extremely irregular in their positions on larger roots; (3) the stem grows upward, while the general direction taken by the roots is downward.



A pocket garden which has been kept in complete darkness for several weeks. Notice the bleached condition of stems and leaves.

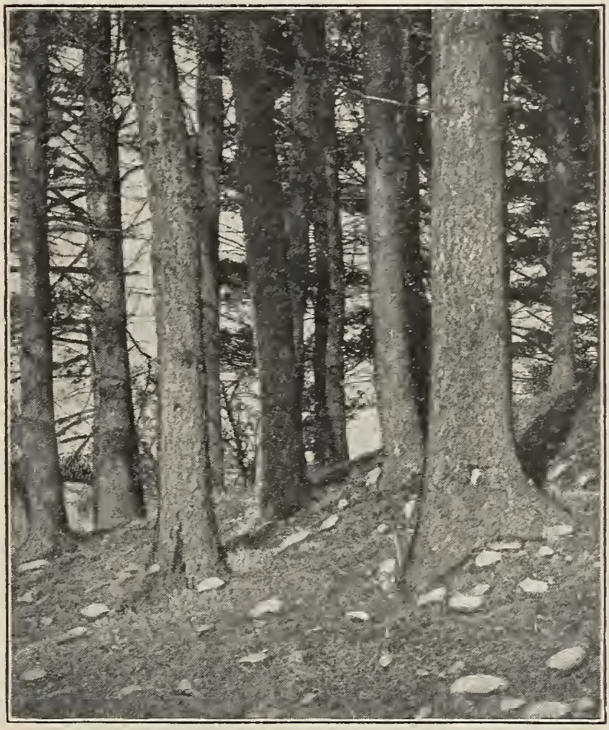
**Effect of Light on Plants.** — In young plants which have been grown in total darkness, no green color is found in either stems

or leaves, the latter often being reduced to mere scales. The stems are long and more or less reclining. We can explain this strange condition of the seedling grown in the dark only by assuming that light has some effect on the protoplasm of the seedling and induces the growth of the green part of the plant. Numerous instances could be given in which plants grown in sunlight are healthier and better developed than those in the shady parts of a garden or field. On the other hand, some plants thrive in the shade.



The growth of young stems and leaves of oxalis toward the light.

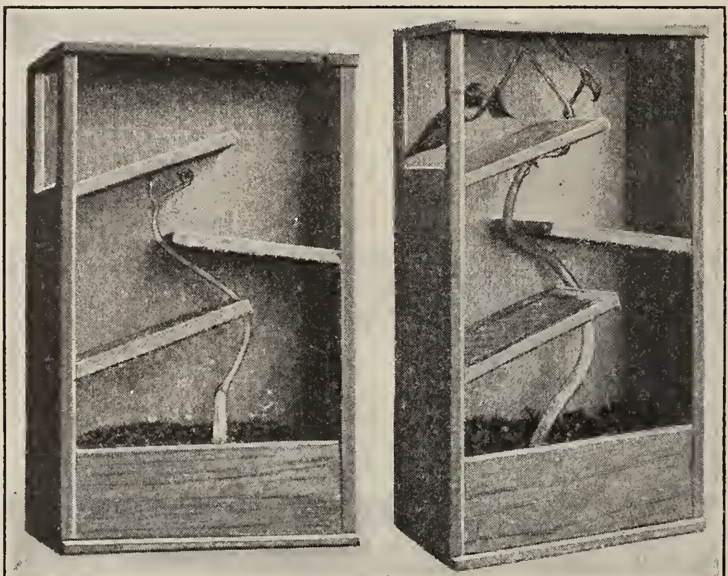
Such plants are the mosses and ferns. Still other plants, minute organisms, some of them invisible to the eye, do not thrive in the light, and may be killed by its influence. Examples of such are found among the molds, mildews, and bacteria. Such plants, however, are not green. As a matter of fact, the stem of a green plant which has but little green coloring matter develops more rapidly under conditions where it receives no light.



Tall straight stems of the hemlock; the trees reach up toward the source of light.

**Heliotropism.** — We saw that the stems of the plants kept in the darkness do not always hold themselves erect, as is the case of most stems in the light. If seedlings have been growing on a window sill, or where the light comes in from one side, you have doubtless noticed that the stem and leaves of the seedlings incline in the direction from which the light comes. *The tendency of young stems and leaves to grow toward sunlight is called positive heliot'ropism.*

The experiment pictured on this page shows this effect of light very plainly. A hole was cut in one end of a cigar box and



Two stages in an experiment to show that green plants grow toward the light.

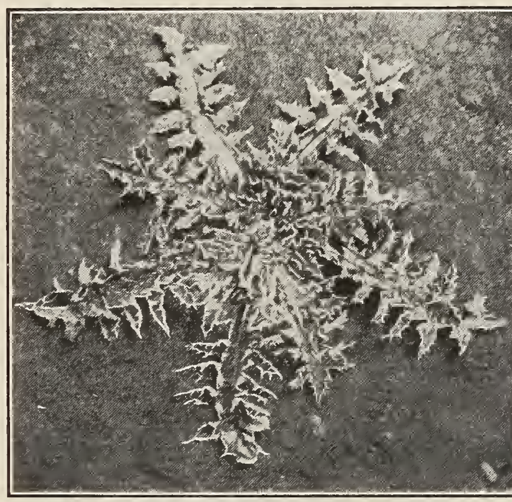
barriers were erected in the interior of the box so that the seedling growing in the sawdust received its light by an indirect course. The young seedling in this case responded to the influence of light and grew out finally through the hole in the box into the open air. This growth of the stem to the light is of very great importance to a growing plant, because, as we shall see later, food making depends largely on the amount of sunlight the leaves receive.

**Effect of Light.** — We have already found that seedlings grown in total darkness are almost yellow-white in color, that the leaves are but slightly developed, and that the stem has developed far more than the leaves. We have also seen that a

green plant will grow toward the source of light, even against great odds. It is a matter of common knowledge that green leaves turn toward the light. Place growing pea seedlings, oxalis, or any other plants of rapid growth near a window which receives full sunlight. Within a short time the leaves are found to be in positions to receive the most sunlight possible.

**Arrangement of Leaves.** — A study of trees in a park, or in the woods, shows that the trunks of trees which are close together

A lily, showing long, narrow leaves.



A dandelion, showing a whorled arrangement of long, irregular leaves.

are usually tall and straight and that the leaves come out in clusters near the top of the tree. The leaves lower down are often smaller and less numerous than those near the top. Careful observation of plants growing outdoors shows us that in almost every case the leaves are so disposed as to get the most sunlight. The ivy climbing up the wall, the morning-glory, the dandelion, and the burdock all show different arrangements of leaves, each presenting a large surface to the light. Leaves are usually definitely arranged, and fitted in between others so as to present their upper surface to the sun. Such an arrangement is known as a *leaf mosaic.* Good examples of such mosaics, or leaf patterns, are seen in trees having leaves which come up alternately, first on one side of a branch, then on the other. Here the leaves turn, by the twisting of their

stalks, so that they all present their upper surface to the sun. In the case of the dandelion, a rosette or whorled cluster of leaves is found. In the horse-chestnut, where the leaves come out opposite each other, the older leaves have longer stems than the young ones. In the mullein the entire plant forms a cone; the old leaves near the bottom have long stalks, and the little ones near the apex come out close to the main stalk. In every case each leaf receives a large amount of light. Other modifications of these forms may easily be found on a field trip.

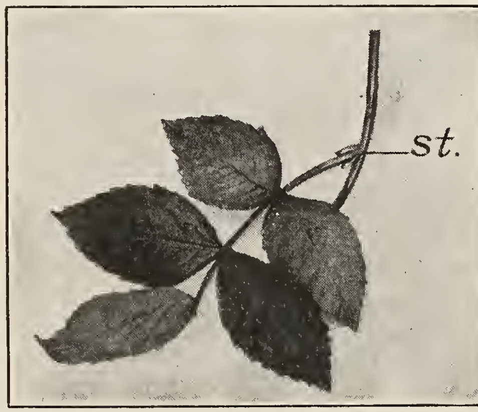
Palmately-veined leaf of the maple.


The skeleton of a pinnately veined leaf: *MR*, midrib; *P*, the leafstalk or petiole; *V*, the veins.

**The Sun a Source of Energy.** — We all know the sun is a source of energy, for do we not feel its heat and is not heat a form of energy? Solar engines have not thus far come into any great use, because fuel is cheaper. Actual experiments have shown that the sun gives to the earth vast amounts of energy. When the sun is in the zenith, energy equivalent to one hundred horse power is received by a plot of land twenty-five by one hundred feet, or the size of a city lot. Plants receive and use much of this energy by means of their leaves.

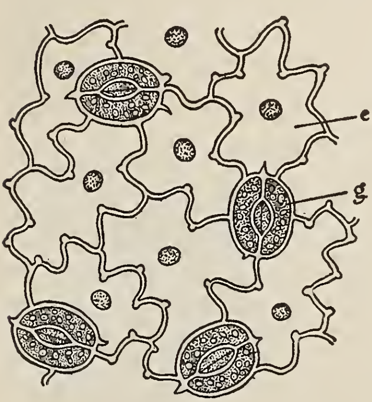
**The Structure of a Leaf.** — Let us now examine with some detail the structure of a simple leaf of a dicotyledonous plant.

A green leaf shows usually (1) a flat, broad *blade* which may take almost any conceivable shape; (2) a stem or *petiole* (pĕt′ĭ-ōl), which spreads out into *veins* in the blade (the veins usually present a netted appearance in the leaf of a dicotyledon, but run more or less parallel to one another in the blade of a monocotyledonous leaf); (3) *stipules,* a pair of outgrowths from the petiole at its base. In many leaves the stipules fall off early. Some leaves are *compound,* that is, each of the little leaflike parts is in reality a section of the leaf blade which is so deeply indented that it is cut away to the *midrib* or central vein, as in the rose leaf. A pair of stipules found at the base shows that such a leaf is compound. The cut just above shows this condition in the rose plant. What other plants commonly seen have compound leaves?



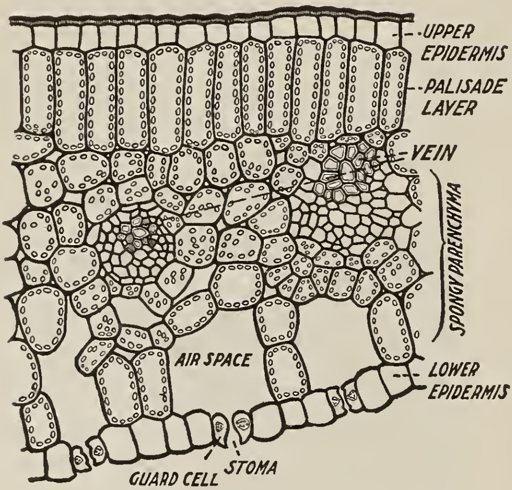
Pinnately-compound leaf of rose, showing stipules *st.*

**The Cell Structure of a Leaf.** — The lower surface of most leaves, as seen under the microscope, shows large numbers of tiny oval openings called *sto′mata* (singular *stoma*). Two cells, usually kidney-shaped, are found, one on each side of the stoma. These are the *guard cells.* By changes in the shape of these cells the opening of the stoma is made larger or smaller. Larger cells (irregular in dicotyledons) form the *epidermis,* or outer covering of the leaf. Study of the leaf in cross section shows that the stomata open directly into air chambers between the loosely arranged



Surface view of epidermis of lower surface of a leaf highly magnified; *e*, ordinary epidermal cell; *g*, guard cell. — Tschirch.

cells composing the lower part of the leaf. The upper surface of leaves sometimes contains stomata, but more often is without them. The under surface of an oak leaf of ordinary size contains about 2,000,000. Under the upper epidermis is a layer of green cells closely packed together, called collectively the *palisade layer.* These cells are more or less columnar in shape. Under them are several rows of rather loosely placed cells containing the air spaces above mentioned. These are called collectively the *spongy parenchyma* (pa-rĕng′kĭ-ma). If we happen to have a section cut through a vein, we find it composed of a number of tubes made up of, and strengthened by, thick-walled cells, the *fibrovascular bundles.* The veins are evidently a continuation of the tubes of the stem out into the blade of the leaf.

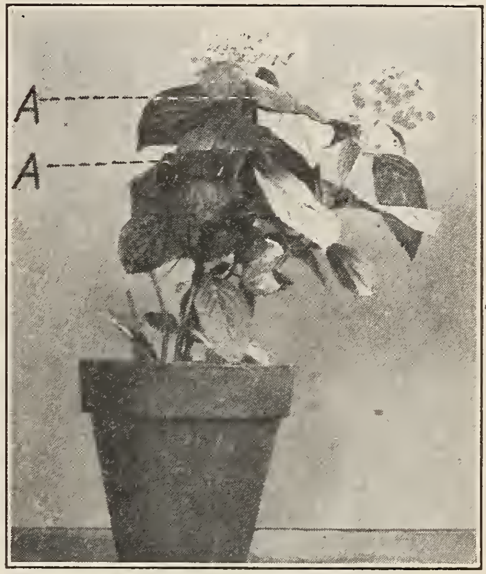



Section of a leaf highly magnified. The cells containing chlorophyll bodies are in the palisade layer and the spongy parenchyma.

**Starch made by a Green Leaf.** — If we examine the palisade layer of the leaf, we find cells which are almost cylindrical in form. In the protoplasm of these cells are found a number of small green-colored bodies, which are known as *chloroplasts* (klō′rō̆-plasts) or *chlorophyl* (klō′rō̆-fĭl) *bodies.* If the leaf is placed in wood alcohol, we find that the bodies still remain, but that the color is extracted, going into the alcohol and giving to it a beautiful green color. The chloroplasts are simply part of the protoplasm of the cell colored green. If the plant is kept in the sun, the chloroplasts retain their green color, but in the dark this color is gradually lost. These bodies are of the greatest importance directly to plants and indirectly to animals. *The chloroplasts, by means of the energy received from the sun, manufacture starch out of certain raw materials.* These raw materials are soil water, which is passed up through the bundles of tubes into the veins of the leaf from the roots, and carbon dioxide,

which is taken in through the stomata or pores which dot the under surface of the leaf.

**Light and Air Necessary for Starch Making.** — Pin strips of black cloth, such as alpaca, over some of the leaves of a growing geranium in such a way that only a part of each leaf is in the dark; and place the plant in a sunny window for two or three days. Then remove some of the partly covered leaves after a day of bright sunlight, and after extracting the chlorophyl with wood alcohol (because the chlorophyl covers up the contents of the cells) test for starch. We find that starch is present only in those portions of the leaves which were exposed to sunlight. From this experiment we infer that the sun has something to do with starch making in a leaf. The necessity of air also for starch making may easily be proved: on a plant placed in the sunlight cover a leaf with vaseline; after several days it will be found to contain no starch, while leaves unvaselined contain starch.




A hydrangea plant, upon the leaves of which strips of black cloth (*A*) have been pinned in order to exclude sunlight.

Starchless area in leaf, caused by excluding sunlight by means of a strip of black cloth.

Air is necessary for the process of starch making in a leaf, not only because carbon dioxide gas is absorbed (there are from three to four parts in ten thousand present in the atmosphere), but also because the protoplasm of the leaf is alive and must have oxygen. These gases are taken in through the stomata of the leaf from the surrounding air.

**Comparison of Starch Making and Milling.** — The manufac-

ture of starch by a green leaf is not easily understood. The process has been compared to the milling of grain; in which case the mill is the green part of the leaf. The sun furnishes the motive power, the chloroplasts constitute the machinery, and soil water and carbon dioxide are the raw materials taken into the mill. The manufactured product is starch, and a certain by-product (corresponding to the waste in a mill) is also given out. This by-product is oxygen. To understand the process more fully, we must refer to a small portion of the leaf. Here we find that the green *palisade cells* perform most of the work. The carbon dioxide is taken in through the stomata and reaches the green cells by way of the intercellular spaces and by diffusion from cell to cell. Water reaches the green cells through the conducting tubes in the veins. It then passes into the cells by osmosis, and there becomes part of the cell sap. The light of the sun easily penetrates to the cells of the palisade layer, giving the energy needed to make the food. This whole process is a very delicate one, and takes place only when external conditions are favorable. For example, too much heat or too little heat stops starch making; the presence of stored food in the leaf has a similar effect on the process. *This building up of starch out of carbon dioxide and water and the release of oxygen by chloroplasts in the presence of sunlight is called photosyn'thesis.*

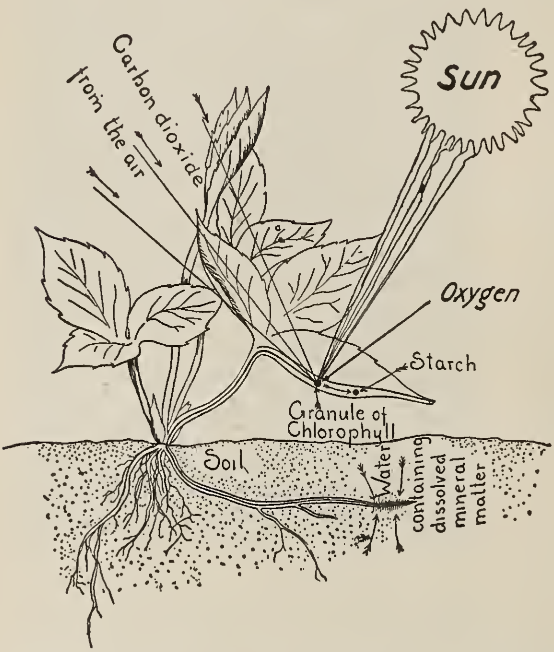


Diagram to illustrate the formation of starch.

**Chemical Action in Starch Making.** — In the process of starch making, water ($H_2O$) and carbon dioxide ($CO_2$) are combined in such a way as to make starch, expressed by the chemical formula $C_6H_{10}O_5$. It is probable that the first product formed in the

leaf is carbonic acid, which assists in making formaldehyde, from which sugar and finally starch is formed. All of these changes are brought about by the action of enzymes which are present in the cells of the leaf and help make food manufacture possible. The starch thus formed is either stored in the leaf or changed by digestion to some soluble form like grape sugar, which can be carried to other parts of the plant, passing from

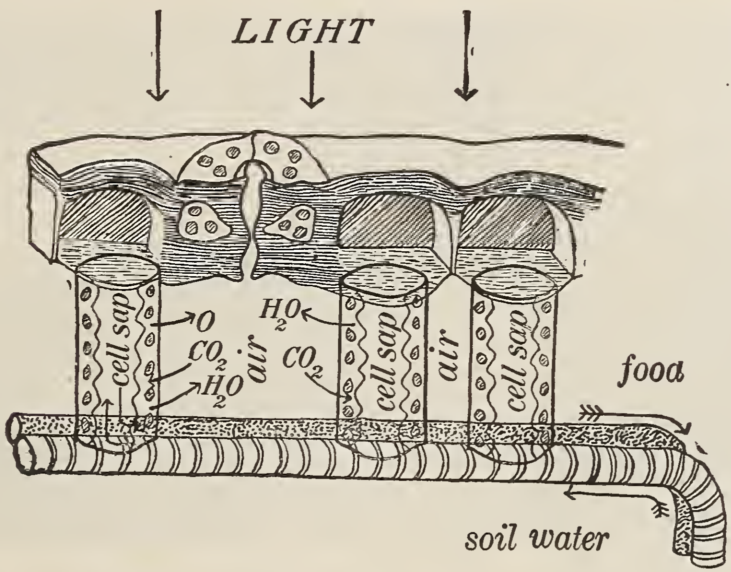


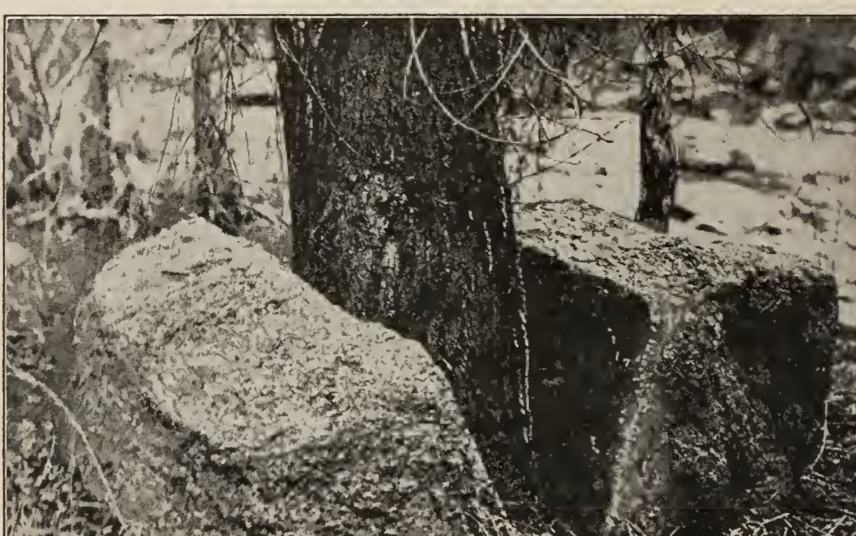

Diagram (after Stevens) to illustrate the processes of breathing, food making, and transpiration which may take place in the cells of a green leaf in the sunlight.

cell to cell by osmosis. The oxygen is passed out through the stomata of the leaf.

**Protein Making and its Relation to the Making of Living Matter.** — Protein material is a food which is necessary for the growth of protoplasm, and is present in the leaf, the stem, and the root. Proteins can apparently be manufactured in any plant cell, the presence of light not being a necessary factor. The element nitrogen is taken up by the roots as a nitrate (nitrogen in combination with lime or potash) in the soil water, and in making protein it unites with the carbon, hydrogen, and oxygen found in starch and sugar. Proteins are probably not made directly into protoplasm in the leaf, but are stored by the cells and used when needed, either to form new cells at a growing

point, or to repair waste. While plants and animals obtain their food in different ways, they probably make it into living substance (*assimilate* it) in exactly the same manner.

Foods serve exactly the same purposes in plants and in animals; they either build living matter or they are burned (oxidized) to furnish energy (work power). If you doubt that a plant exerts energy, note how the roots of a tree bore their



An example of how a tree may exert energy. This rock has been split by the growing tree. Photograph from the American Museum of Natural History.

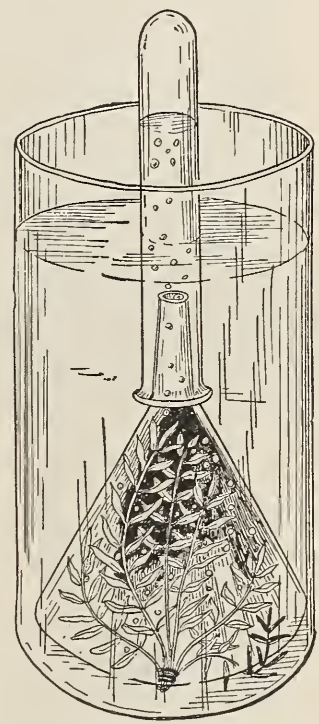
way through the hardest soil, and how stems or roots of trees often split open solid rocks, as illustrated in the Figure.

**Rapidity of Starch Making.** — Leaves which have been in darkness show starch to be present shortly after being exposed to light. Squash leaves make three fourths of an ounce of starch for each square yard of surface. A corn plant sends 10 to 15 grams of reserve material into the ears in a single day. This fact explains how the rapid growth seen in grain fields or a fruit orchard may occur and is of economic importance. Not only do plants make their own food but they store it away, and it becomes food for animals as well. It is fortunate that the food is stored in such a stable form in grain or other fruits that it may be sent to all parts of the world without spoiling. Animals, herbivorous and flesh-eating, even man himself, all are

dependent upon the starch-making processes of the green plant for the ultimate source of their food.

**Oxygen given off by Green Plants.** — It is possible to prove that oxygen is given off by green plants in sunlight. The common green frog scum seen in shallow ponds is often so full of bubbles that it is buoyed up by them at the water's surface. If some of this plant or other green water weed is placed in a large battery jar or fruit jar in a sunny window, bubbles of gas will be seen to arise from it, the amount increasing as the water is warmed by the sun's rays.

If a glass funnel is placed upside down so as to cover the plants, and then a test tube full of water inverted over the mouth of the funnel, enough gas may be collected to test for oxygen.[1]



Experiment to show that oxygen is given off by green plants in the sunlight.

That oxygen is given off as a by-product when starch is made by green plants is a fact of far-reaching importance. Parks in a city are true "breathing spaces." The green covering of the earth is giving to animals an element that they must have, while the animals in their turn are supplying to the plants carbon dioxide, a compound used in food making. Thus a relation of mutual helpfulness exists between plants and animals.

**Evaporation of Excess Water.** — In order to secure the necessary amount of mineral matter for the manufacture of foods, an enormous amount of water is taken up by the roots and passed to the leaves, where the minerals which were in solution in the soil water are deposited and the excess water is evaporated through the stomata. The process of giving off water in

[1] Water contains air in solution, including some carbon dioxide, but the amount of this gas in a jar of ordinary water may be too small. Immediate success with this experiment will be obtained if the water has been previously charged with carbon dioxide.

the form of vapor is known as *transpiration.* That moisture is passed out through the blade of the leaf is shown by the diagram below, drops of water having gathered on the inside of the bell jar. A small grass plant on a summer's day evaporates more than its own weight in water. This would make nearly half a ton of water distributed to the air during twenty-four hours by a grass plot twenty-five by one hundred feet, the size of the average city lot.

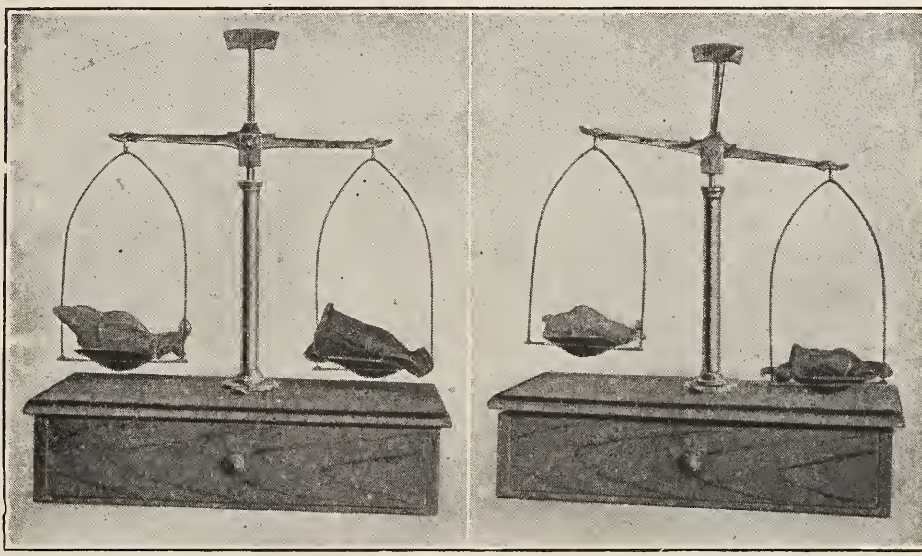
Experiment to show transpiration. The top of the flower pot is covered with rubber. The moisture comes from the leaves.

**From which Surface of the Leaf is Water Lost? Experiment.** — In order to find out whether water is passed out from any particular part of the leaf or not, we may remove two leaves of the same size and weight from some large-leaved plant — a mullein was used for the illustrations on the opposite page — and cover the upper surface of one leaf and the lower surface of the other with vaseline. The petioles of both should be covered with wax or vaseline, and the two leaves exactly balanced on the pans of a balance which has previously been placed in a warm and sunny spot. Within an hour the leaf which has the upper surface covered with vaseline will show a loss of weight. Microscopic examination of the epidermis of a mullein leaf shows us that the lower surface of the leaf is provided with stomata. It is through these openings that water is passed out from the tissues of the leaf.

**Regulation of Transpiration.** — The stomata of leaves close at night, the guard cells apparently being sensitive to light, and prevent the transpiration of much water. There is little loss of water on humid days, because of the large amount of water in the atmosphere. When the plant has water and the atmosphere is dry, the stomata open and give off water vapor. But the exact means by which regulation of evaporation through the stomata takes place is not well understood.

**The Effect of Transpiration on Water within the Stem.** — It

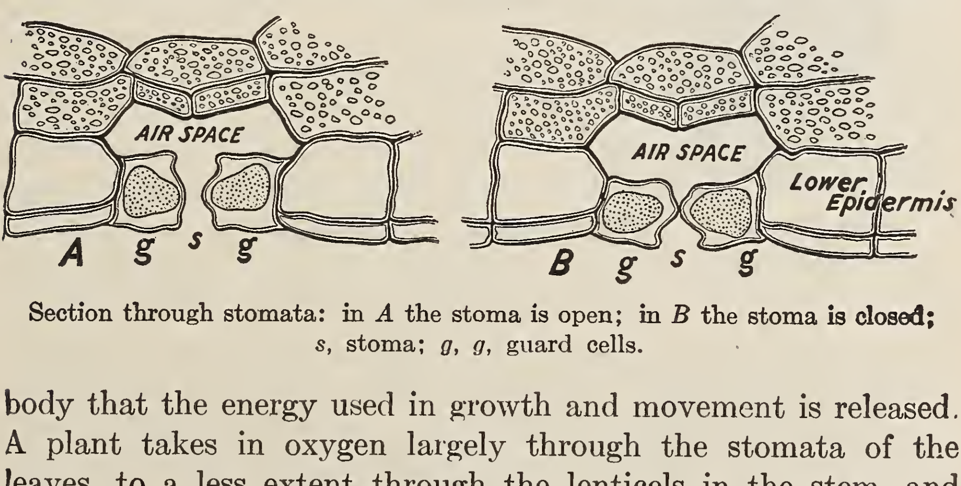
has already been noted that root pressure alone will not account for the rise of water to the tops of very tall trees. Experiments indicate that evaporation of water through the stomata exerts a



Experiment to show through which surface of a leaf water vapor passes off.

pull upon the tiny column of water held together by cohesion within the stem of the tree, thus causing the rise of water to the leaves on the upper branches.

**Respiration by Leaves.** — All living things require oxygen. It is by means of the oxidation of food materials within the plant's




Section through stomata: in *A* the stoma is open; in *B* the stoma is closed; *s*, stoma; *g*, *g*, guard cells.

body that the energy used in growth and movement is released. A plant takes in oxygen largely through the stomata of the leaves, to a less extent through the lenticels in the stem, and through the roots. Thus rapidly growing tissues receive the

oxygen necessary for them to perform their work. The products of oxidation in the form of carbon dioxide are also passed off through the same organs. It can be shown by experiment that a plant uses up oxygen in the darkness; in the light the amount of oxygen given off as a by-product in the process of starch making is, of course, much greater than the amount used by the plant.

**Economic Uses of Leaves.** — The practical use of green plants to man is very great. They give off oxygen in the sunlight and use carbon dioxide, which is given off by animals in respiration. We should remember, as taxpayers, that money spent on city parks is money well invested, bringing as it does a source of oxygen supply where it is most needed.

A cactus, showing the leaves modified into spines.

Another very important use of leaves to man is seen in the fact that after falling to the ground, they help to form a rich covering of humus, which acts as a coat to hold in moisture. The forests are our greatest source of water supply. The cutting away of the forest always means a depletion of the reserve water stored in soil, with consequent floods and droughts in alternation.

Leaves are used directly by man for food. Examples are cabbage, lettuce, kale, and broccoli. These foods, properly combined with fleshy foods, are of great importance in giving a balance to diet. In a wider sense, all animals depend upon leaves for their food supply, either directly or indirectly. Foods obtained from roots, stems, seeds, and fruits were manufactured in the leaves and transported within the plant to their places of storage. Even meat-eating animals are in the long run dependent upon plants, for they feed upon plant eaters.

**Modified Leaves.** — Leaves, as well as stems, may be modified for the protection of the plant. In some cacti, for example, in order to prevent too rapid evaporation of water, the leaves have been changed into spines. In other plants, as the mullein, the leaves are covered with protective hairs. In still others the leaves may be reduced or lost entirely, as in the asparagus. We have already noted that some leaves have become modified for climbing purposes.

**Leaves as Insect Traps.** — The most curious adaptations of leaves are seen, however, in those plants whose leaves have been


Leaves modified to serve as insect traps: *A*, pitcher plant; *B*, sundew; *C*, Venus's flytrap.

modified to catch and feed upon insects. It sometimes happens that the environment of a plant will not supply the nitrogen necessary for growth. Certain species of plants, therefore, by means of either bladder-like leaves, as in the bladderwort and pitcher plant, or actual traps, as are seen in the sundew and Venus's flytrap, catch and actually use the bodies of the insects as food. The accompanying illustrations show how this is done.

**Summary.** — This chapter shows us (1) that light plays an important part in not only attracting stems and leaves but also in helping to make food; (2) that the structure of a leaf fits it to be a starch making as well as a breathing organ; it also

makes protein, gives off oxygen as a by-product of starch making, and gives off water by transpiration; (3) that starch making requires light, carbon dioxide, water, and chlorophyll in addition to the delicate mechanism of the leaf; (4) that various modifications of leaves serve for protection, storage of water, climbing, and catching of insects for food, the last curious modification being brought about by lack of available nitrogen in the environment.

**Problem Questions.** — 1. What is heliotropism? Give examples.

2. Prove all energy comes from the sun.

3. Describe the microscopic structure of a leaf.

4. Describe the process of photosynthesis.

5. What other functions has the green leaf of a growing plant?

6. Sum up the economic uses of green plants to the world.

7. Describe five adaptive modifications of green leaves.

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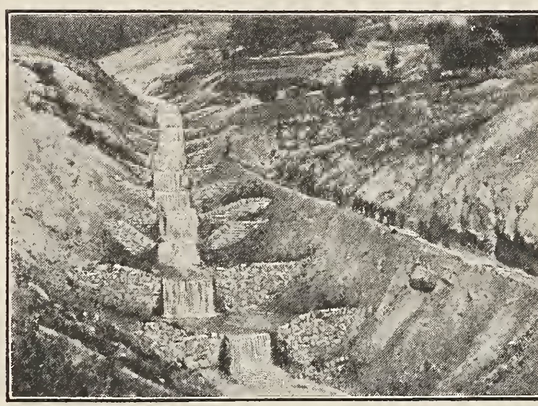
# X. OUR FORESTS; THEIR USES AND THE NECESSITY FOR THEIR PROTECTION

***Problem.*** *To determine some uses of stems (optional). (Laboratory Manual, Prob. XIX; Laboratory Problems, Probs. 80–84.)*
(*a*) *Special products from stems.*
(*b*) *Some woods and their value.*
(*c*) *Field work in forestry.*

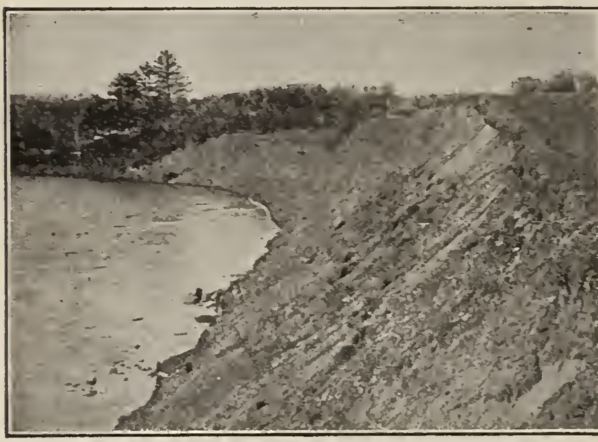
**The Economic Value of Trees. Protection and Regulation of Water Supply.** — Trees form a protective covering for the earth's surface. They prevent soil from being washed away, and they hold moisture in the ground. Without trees many of our rivers might go dry in summer, while in the rainy season sudden floods would result. The devastation of immense areas in China and considerable damage by floods in parts of Switzerland, France, and in Pennsylvania, have resulted where the forest covering has been removed. No one who has tramped through our Appalachian forests can escape noticing the differences in the condition of streams which flow through areas covered with forest and those from around which trees have been cut. The latter streams often dry up entirely in hot weather, while the forest-shaded stream has a never failing supply of crystal water.



Working to prevent erosion after the removal of the forest in the French Alps.

Several cities on the Atlantic coast, such as Savannah, Wilmington, and Philadelphia, owe their importance to their po-

sition on navigable rivers supplied with water largely by the Appalachian forests. Should these forests be destroyed, it is not impossible that the frequent freshets which would follow would so fill the rivers with silt and débris that the ship channels in them, already costing the government millions of dollars a year to keep dredged, would become too shallow for ships. If this should occur, these cities would soon lose their importance.



Erosion at Sayre, Pa., by the Chemung River.
Photographed by W. C. Barbour.

The story of how this very thing happened to the old Greek city of Poseidonia is graphically told in the following lines:

"It was such a strange, tremendous story, that of the Greek Poseidonia, later the Roman Pæstum. Long ago those adventuring mariners from Greece had seized the fertile plain which at that time was covered with forests of great oak and watered by two clear and shining rivers. They drove the Italian natives back into the distant hills, for the white man's burden even then included the taking of all the desirable things that were being wasted by incompetent natives, and they brought over colonists — whom the philosophers and moralists at home maligned, no doubt, in the same pleasant fashion of our own day. And the colonists cut down the oaks, and plowed the land, and built cities, and made harbors, and finally dusted their busy hands and busy souls of the grime of labor and wrought splendid temples in honor of the benign gods who had given them the possessions of the Italians and filled them with power and fatness.

"Every once in so often the natives looked lustfully down from the hills upon this fatness, made an armed snatch at it, were driven back with bloody contumely, and the heaping of riches upon riches went on. And more and more the oaks were cut down — mark that! for the stories of nations are so inextricably bound up with the stories of trees — until all the plain was cleared and tilled; and then the foothills were denuded, and the wave of destruction crept up the mountain sides, and they, too, were left naked to the sun and the rains.

"At first these rains, sweeping down torrentially, unhindered by the

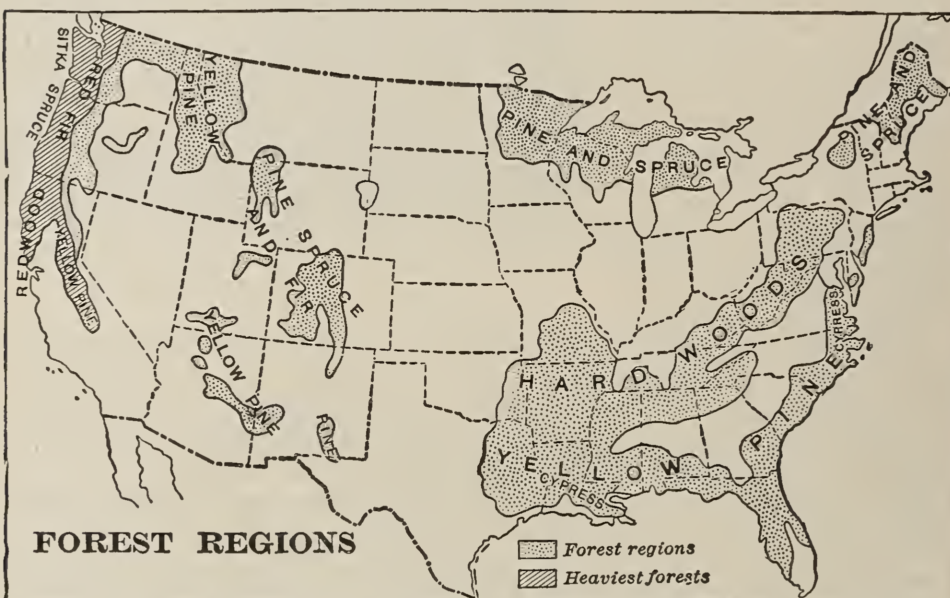
lost forests, only enriched the plain with the long-hoarded sweetness of the trees; but by and by the living rivers grew heavy and thick, vomiting mud into the ever shallowing harbors, and the land soured with the undrained stagnant water. Commerce turned more and more to deeper ports, and mosquitoes began to breed in the brackish soil that was making fast between the city and the sea.

"Who of all those powerful landowners and rich merchants could ever have dreamed that little buzzing insects could sting a great city to death? But they did. Fevers grew more and more prevalent. The malaria-haunted population went more and more languidly about their business. The natives, hardy and vigorous in the hills, were but feebly repulsed. Carthage demanded tribute, and Rome took it, and changed the city's name from Poseidonia to Pæstum. After Rome grew weak, Saracen corsairs came in by sea and grasped the slackly defended riches, and the little winged poisoners of the night struck again and again, until grass grew in the streets, and the wharves crumbled where they stood. Finally, the wretched remnant of a great people wandered away into the more wholesome hills, the marshes rotted in the heat and grew up in coarse reeds where corn and vine had flourished, and the city melted back into the wasted earth."— Elizabeth Bisland and Anne Hoyt, *Seekers in Sicily*. John Lane Company.

**Prevention of Erosion by Covering of Organic Soil.** — Streams unprotected by forests may dig out soil and carry it far from its original source. Examples of what streams have done may be seen in the deltas formed at the mouths of great rivers. The forest prevents this by holding back the water and letting it out gradually. This it does by covering the inorganic soil with humus or decayed organic material which, like a big sponge over the forest floor, holds water through long periods of drought. The roots of the trees, too, help hold the soil in place and prevent erosion. The gradual evaporation of water through the stomata of the leaves cools the atmosphere, and this tends to precipitate the moisture in the air. Eventually the dead bodies of the trees themselves are added to the organic covering, and new trees take their place.

**Other Uses of the Forest.** — In some localities forests are used as windbreaks and to protect mountain towns against avalanches. In winter they moderate the cold, and in summer reduce the heat and lessen the danger from storms. The nesting of birds in woods protects many plants valuable to man which otherwise might be destroyed by insects.

Forests have great commercial importance as well. Even in this day of coal, wood is still by far the most-used fuel. It is useful in building. It outlasts iron under water, in addition to being strong and light. It is cheap and, with care of the forests, inexhaustible, while our mineral wealth will some day be used up. Hard woods are chiefly used in house building and furniture manufacture; many soft woods, reduced to pulp, are made into paper. Distilled wood gives alcohol. Partially burned wood is charcoal. Vinegar and other acids are ob-



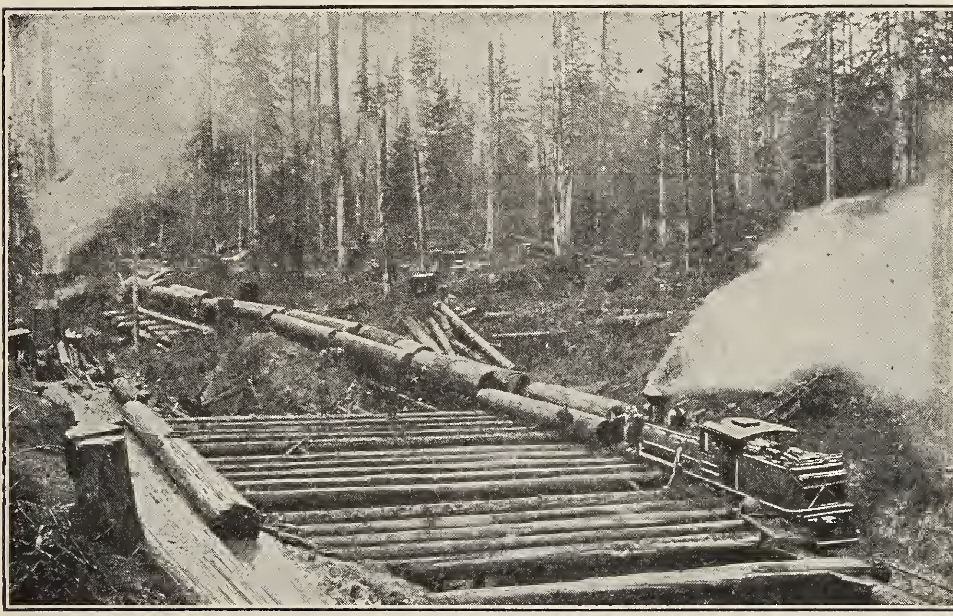

The forest regions of the United States.

tained from trees, as are tar, creosote, resin, turpentine, and other useful oils. The making of maple sirup and sugar forms a profitable industry in several states.

**The Forest Regions of the United States.** — The combined area of all the forests in the United States, exclusive of Alaska, is about 550,000,000 acres. This seemingly immense area is rapidly decreasing in acreage and in quality, thanks to the demands of an increasing population, a woeful ignorance on the part of the owners of the land, and wastefulness on the part of cutters and users alike.

A glance at the map shows the distribution of our principal

forests. At the present time they occupy about 35 per cent of the total area of the country. But lumbering is still one of our greatest industries and so heedless are we for the future that at the present time we are cutting our forests three times as fast as they are being renewed by natural growth. Moreover the waste in production is enormous, it being estimated that over 65 per cent of a tree is wasted before it is used by man. Washington



Transporting logs from the forest to the mill, Washington.

ranks first of all the states in the production of lumber. Here the great Douglas fir, one of the "evergreens," forms the chief source of supply. In the Southern states, especially Louisiana and Mississippi, yellow pine and cypress are the trees most lumbered.

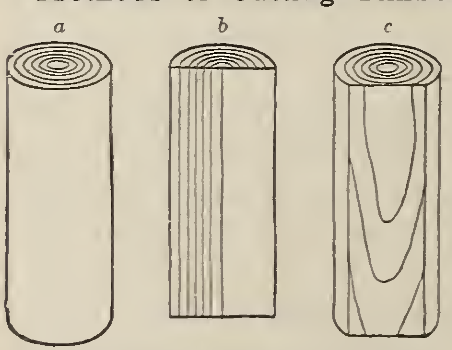
**Uses of Wood.** — In our forests much of the soft wood (the cone-bearing trees, spruce, balsam, hemlock, and pine), and poplars, aspens, basswood, with some other species, are made into paper. The daily newspaper and cheap books are responsible for inroads on our forests which cannot well be repaired. It is not necessary to take the largest trees to make paper pulp; hence many young trees of not more than six inches in diameter are sacrificed. Of the hundreds of species of trees in our forests,

the conifers are probably most sought after for lumber. Pine, especially, is probably used more extensively than any other wood. It is used for all heavy construction work, frames of houses, bridges, masts, spars, and timber of ships, floors, railway ties, and many other purposes. Cedar is used for shingles, cabinetwork, lead pencils, etc.; hemlock and spruce for heavy timbers and, as we have seen, for paper pulp. Another use for our lumber, especially odds and ends of all kinds, is in the packing-box industry. It is estimated that nearly 50 per cent of all the lumber cut finds its way ultimately into the construction of boxes. Hemlock bark is used for tanning.

The hard woods, ash, basswood, beech, birch, cherry, chestnut, elm, maple, oak, and walnut, are used largely for the "trim" of our houses, for manufacture of furniture, wagon or car work, and endless other purposes.

**Structure of Wood.** — Quite a difference in color and structure is often seen between the heartwood, composed of the dead walls of cells occupying the central part of the tree trunk, and the sapwood, the living part of the stem. In trees which are cut down for use as lumber and in the manufacture of various kinds of furniture, the markings and differences in color are not always easy to understand.

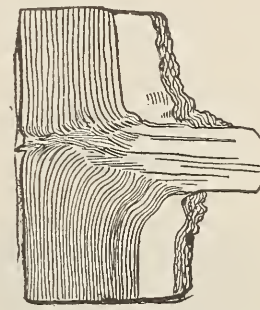
**Methods of Cutting Timber.** — A glance at the diagram of the sections of timber shows us that a tree may be cut radially through the middle of the trunk or tangentially to the middle portion. Most lumber is cut tangentially. Hence the annual rings appear in a more or less irregular arrangement, causing grain in the wood, and the elliptical markings seen in many school desks.




Diagrams of sections of timber: *a*, cross section; *b*, radial; *c*, tangential. (From Pinchot, U. S. Dept. of Agr.)

**Knots.** — Knots, as can be seen from the diagram on the following page, are branches which at one time started in their outward growth and were for some reason killed. Later, the tree, continuing in its outward growth, surrounded them and covered

them up. A dead limb should be pruned before such growth occurs. The markings in bird's-eye maple are caused by adventitious buds which have not developed, and have been overgrown with the wood of the tree.



Section of tree trunk showing knot.

**Destruction of the Forest.** *By Waste in Cutting.* — Man is responsible for the destruction of one of this nation's most valuable assets. This is primarily due to wrong and wasteful lumbering. Hundreds of thousands of dollars' worth of lumber is left to rot annually because the lumbermen do not cut the trees close enough to the ground, or because through careless felling of trees many other smaller trees are injured. There is great waste in the mills. In fact,

A forest in the Far West totally destroyed by fire and by wasteful lumbering.

man wastes lumber in every step from the forest to the making of the finished product.

*By Fire.* — It is estimated that at the present time five sixths of our original timber has been cut or burned. During

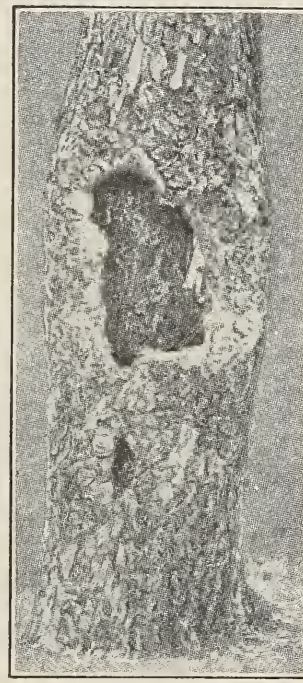
the past five years an area greater than that covered by the New England states has been destroyed by fire. Indirectly, man is responsible for fire, one of the greatest enemies of the forest. Most of the great forest fires of recent years, the losses from which total in the hundreds of millions, have been due either to railroads or to carelessness in setting fires in the woods. It is estimated that in forest lands traversed by railroads from 25 per cent to 90 per cent of the fires are caused by coal-burning locomotives. For this reason laws have been made in New York state requiring locomotives passing through the Adirondack forest preserve to burn oil instead of coal. This has resulted in a considerable reduction in the number of fires. In addition to the loss in timber, the fires often burn out the organic matter in the soil (the "duff") forming the forest floor, thus preventing the growth of other trees there for many years to come. In New York and other states fires are prevented by an organized corps of fire wardens, whose duty it is to watch the forest and fight forest fires.

Woodpeckers and other birds protect the forest by eating destructive insects. Photograph from American Museum of Natural History.

*Other Enemies.* — Other enemies of the forest are numerous fungous plants of which we shall learn more later, insect parasites, which bore into the wood or destroy the leaves, and grazing animals, particularly sheep. Wind and snow also annually kill many trees.

**Forestry.** — The American forests have long been our pride. In Germany, especially, the importance of the forest has long been recognized, and the German forester or caretaker of the

forests is well known. In some parts of central Europe, the value of the forests was seen as early as the year 1300 A.D., and many towns consequently bought up the surrounding forests. The city of Zurich has owned forests in its vicinity for at least 600 years. In this country only recently has the importance of preserving and caring for our forests been noted by our government. Now, however, we have a Forest Service in the U. S. Department of Agriculture; and this and numerous state and university schools of forestry are rapidly teaching the people of this country the best methods for the preservation of our forests. The Federal Government has set aside a number of tracts of mountain forest in some of the Western states, making a total area of over 167,000,000 acres. New York has established for the same purpose the Adirondack Park, with nearly 1,500,000 acres of timber land; Pennsylvania has a park of 700,000 acres, and many other states have followed their example.

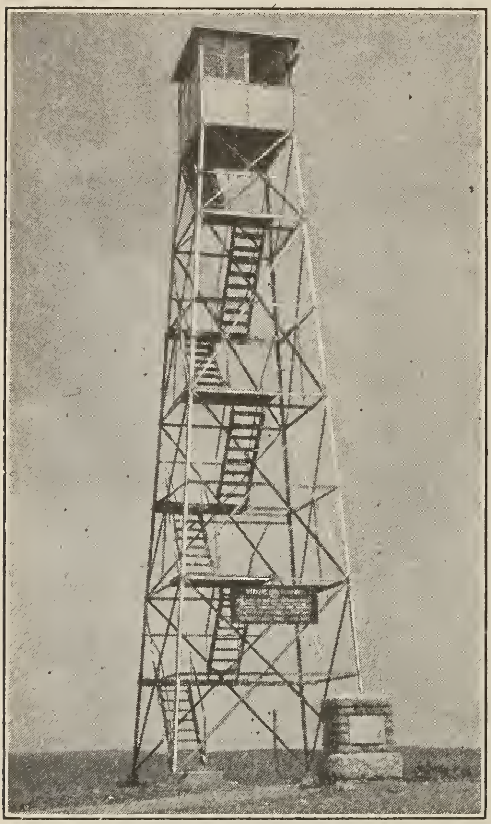


We must protect our city trees. A tree badly wounded by "cribbing" of horses.

**Methods for Keeping and Protecting the Forests.** — Forests should be kept thinned. Too many trees are as bad as too few. They struggle with one another for foothold and light, which only a few can enjoy. The cutting of a forest should be considered as a harvest. The oldest trees are the "ripe grain," the younger trees being left to grow to maturity. Several methods of renewing the forest are in use in this country. (1) Trees may be cut down and young ones allowed to sprout from the stumps. This is called coppice growth. This growth is well seen in parts of New Jersey. (2) Areas or strips may be cut out so that seeds from neighboring trees are carried there to start new growth. (3) Forests may be artificially planted. Two seedlings planted for every tree cut is a rule followed in Europe. The greatest dangers are from fire

and from careless cutting, and these dangers may be kept in check by the efficient work of our national and state foresters.

**A City's Need of Trees.** — All over the United States the city governments are beginning to realize what European cities have long known, that trees are of great value to a city. Many cities are spending money not only to plant trees, but for proper protection to those already growing. Thousands of city trees are annually killed by horses which "crib" upon them (Figure, p. 123). This may be prevented by proper protection of the trunk.



Forest ranger on steel lookout tower, watching for forest fires. This tower is connected with others by telephone. Photograph from Pennsylvania Department of Forestry.

**The Forester and his Work.** — A new and attractive profession has opened in recent years for young men who are fond of the great out-of-doors. Forest rangers are state or national officials whose duty it is to protect the forests. They watch for and fight fires, patrol sections of forest to prevent illegal cutting, regulate cattle grazing in forest reserves, and in general watch over our great national asset, the forests.

Foresters are appointed by private interests also to take practical charge of the care and growth of the forests.

Chicago has appointed a city forester, who has given the following excellent reasons why trees should be planted in the city:

(1) Trees are beautiful in form and color, inspiring a constant appreciation of nature.

(2) Trees enhance the beauty of architecture.

(3) Trees create sentiment, love of country, state, city, and home.

(4) Trees have an educational influence upon citizens of all ages, especially children.

(5) Trees encourage outdoor life.

(6) Trees purify the air.

(7) Trees cool the air in summer and radiate warmth in winter.

(8) Trees improve climate and conserve soil and moisture.

(9) Trees furnish resting places and shelter for birds.

(10) Trees increase the value of real estate.

(11) Trees protect the pavement from the heat of the sun.

(12) Trees counteract adverse conditions of city life.

Let us all try to make Arbor Day what it should be, a day for planting and caring for trees; for thus we may help to preserve this most important heritage of our nation.

**Summary.** — Forests are of much importance because they (1) regulate our water supplies, (2) prevent erosion, (3) change climate, (4) are of great commercial importance. The enemies of the forest are wind and other natural forces, fire, and man's carelessness in cutting, and his unwillingness to look forward into the future. The cure will come through conservation, tree planting, and the work of the foresters.

**Problem Questions.** — 1. Describe ten uses of the forest.

2. How might cities depend upon the forest?

3. Describe five methods of forest destruction.

4. How can you help to prevent forest destruction?

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# XI. THE VARIOUS FORMS OF PLANTS AND HOW THEY REPRODUCE THEMSELVES

**Problem.** *How to know some forms of plant life.* (*Optional.*) (*Laboratory Manual, Prob. XX; Laboratory Problems, Probs. 114, 115.*)

(*a*) *An alga.*
(*b*) *A fungus.*
(*c*) *A moss.*
(*d*) *A fern.*

**Adaptation to Environment.** — Plants, as well as animals, are greatly affected by what immediately surrounds them, — their environment. We have shown in our experiments that a variation in the environment (conditions of temperature, moisture, light, etc.) is capable of changing or modifying the structure of plants very greatly. *The changes which a plant or animal has undergone, that fit it for conditions in which it lives, are called adaptations to environment.*

A red seaweed, an example of a thallus body.

The first plants probably lived in the water. Most of the plants which are simplest in structure still live in the water. In such plants we can distinguish no root, stem, or leaf. This simplest form of plant body is called a *thallus.* It may consist of a single cell or of many cells; it may be of various shapes; but a thallus never has the organs belonging to higher plants.

A red seaweed, showing a finely divided thallus body.

It seems likely that, as more land appeared on the earth's surface, plants be-

came adapted to changed conditions of life on dry land. With this change in environment came a need of taking in water, of storing it, and of conducting it to various parts of the organism. Thus we may imagine how plants came to have roots, stems, and leaves, adapted to their environment on dry land. We find in nature that those plants and animals which are best adapted

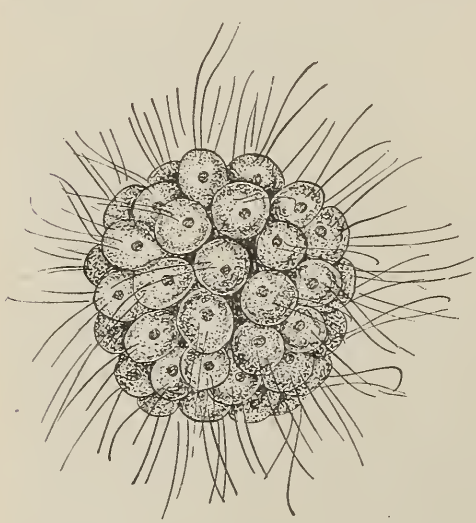
Rockweed, a brown alga, showing the distribution on rocks below high-water mark.

or fitted to live under certain conditions are the ones which survive and drive other competitors out from their immediate neighborhood. Nature selected those which were best fitted to live on dry land, and they have eventually covered the earth with their progeny. Gradually the forms of life grew more and more complex until at last very complicated organisms such as the flowering plants developed. Between the flowering plant and the simplest of all plants are several great plant groups which show steps in complexity of structure between the most lowly and the most highly specialized plants. The simplest of all these forms are the algæ (ăl′jē).

**Algæ.** — The algæ are a diverse collection of plants, con-

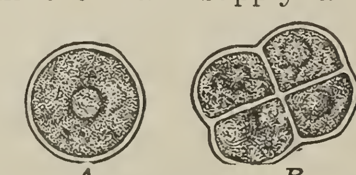
taining forms of many shapes and sizes. The body of an alga is a thallus; it may be platelike, circular, ribbon-formed, threadlike, filamentous, or even composed of a single cell. A large number of the algæ inhabit the water. In color they vary from green through the shades of blue-green to yellow, brown, and red. The latter colors are best seen in the seaweeds, all of which, however, contain chlorophyll.

**Green Algæ.** — The plants known as the *green algæ* are of great interest to us because of their distribution in fresh water, and also because of their economic importance as a supply of oxygen for fish and other animals in the waters of our inland lakes and rivers. Our attention is called to them in an unpleasant way at times, when, after multiplying very rapidly during the hot summer, they die suddenly in the early fall and leave their remains in our water supply. Much of the unpleasant taste and odor of drinking water comes from this cause.



Synura.

The city of New York has recently had an unpleasant experience with a tiny alga called *synu'ra.* This little plant, although harmless, gives an oily, disagreeable taste to water. One part of the water supply in which synura was present in large numbers had to be cut off from the main supply and treated before it was fit for use. Such experiences are not uncommon and are usually prevented by treating with copper sulphate in dilution.



*A* *B*

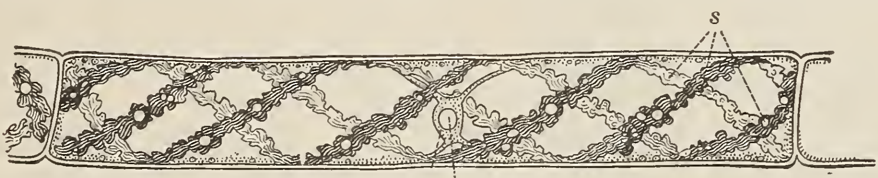
Pleurococcus. *A*, single cell; *B*, colony of four cells formed from the original cell *A*.

**Pleurococcus.** — Many other forms of algæ are common. One of the simplest is *pleurococcus* (plōō-rō-kŏk′us). This little plant consists of a single tiny cell, which by division may give rise to two or even more cells which cling together

in a mass. The green color on tree trunks, stone houses, etc., is often due to millions of these little plants.

**Diatoms.** — These plants are found in vast numbers living on the mud or stones at the bottom of small streams. The plant body is inclosed in a cell wall composed largely of silica. Many of the diatoms are free-swimming. They compose a large percentage of the living organisms found near the ocean's surface.

**Pond Scum** (*Spirogyra*). — This alga is well known to every boy or girl who has observed a small pond or sluggish stream. It grows as a slimy mass of green threads or filaments. Under the low power of the microscope, the body of a thread of pond



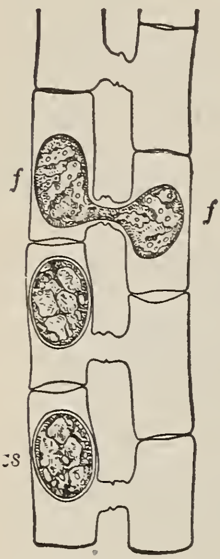

Spirogyra: *n*, nucleus; *s*, chlorophyll bands.

scum is seen to be made up of elongated cylindrical cells, each of which contains a spirally wound band of chlorophyll bodies. Careful study shows the presence of a nucleus held in the body of the cell by strands of protoplasm, the remainder of the space within the cell being a large vacuole filled with cell sap.

Pond scum may grow by simple division of the cells in a filament. This method of *asexual* reproduction is the way growth takes place in the cells of the root, stem, or leaf of a flowering plant, but another method of reproduction is also seen in pond scum. The cells of two adjoining filaments may push out tubes which meet, thus connecting the cells with each other. Meantime the protoplasm of the cells thus joined condenses into two tiny spheres; the bands of chlorophyll are broken down, and ultimately the contents of one of the cells passes through the connecting tube and mingles with the cell of the neighboring filament. The result of this process of fusion is a thick-walled resting cell which is called a *zygospore* (zī′gō-spōr). The cell thus formed can withstand considerable extremes of heat and cold, and may be dried to such an extent that it is found in dust

or floating in the air. Under favorable conditions, this spore will germinate and produce a long filament by asexual reproduction.

**Conjugation.** — *The process by which two cells of equal size unite to form a single cell is called conjugation.* It is believed to be a *sexual* process which corresponds in a way to fertilization in the higher plants.




Conjugation of Spirogyra; *zs*, zygospore; *f*, fusion in progress.

**Fungi.** — The simplest plants, of which we have just seen examples, are called *thallophytes* (thăl′ō-fīts). Of these there are two groups, the *algæ* or plants containing chlorophyll, and the *fungi* (fŭn′jī), or those which do not contain chlorophyll. As a direct result of the lack of chlorophyll in the cells, the fungi are unable to make their own food. They must obtain food from other plants or animals. *Some take up their abode upon living plants or animals, in which case they are called parasites; others obtain their food from dead organic matter and are called saprophytes* (săp′rō-fīts). The above facts make the group of the fungi of immense economic importance to man. We shall consider several of these plants in their direct relation to the human race.

**Mosses.** — These are mostly shade-loving and moisture-loving plants. They form velvety carpets in many of our forests, but they often show their preference for moist localities by covering the wooded shores of lakes and swamps.

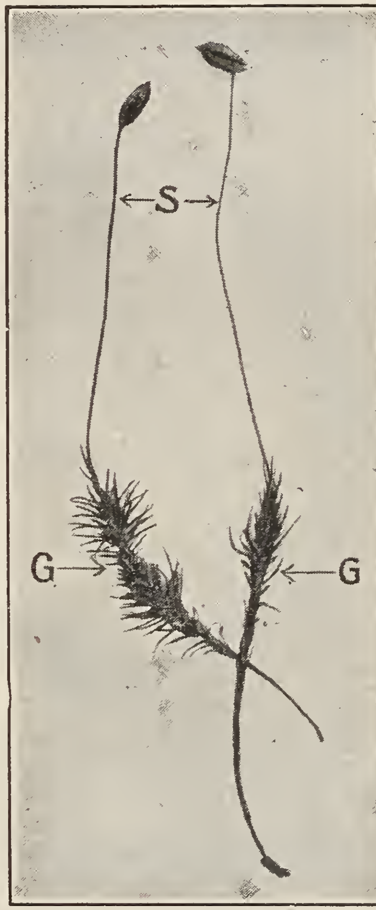
**Pigeon-wheat Moss.** — One of the mosses frequently seen and easily recognized is the so-called pigeon-wheat moss. The resemblance of a large number of these plants to a mimic field of grain has given the name pigeon-wheat to this form.

**Forms of Moss Plants.** — Three kinds of moss plants appear to be present: leafy plants, others bearing a stalk and capsule, and still others which terminate at the end in a little rosette of leaves, inclosing what appears to be a tiny flower.

*Leafy Moss Plant.* — A leafy moss plant has rhizoids (rī′zoidz) or hair-like roots, an upright stem, and green leaves. In the

plants which have a stalk and capsule, the stalk grows directly from the end of the leafy plant.

*Sporophyte.* — The capsule is the spore-producing part (*sporan′gium*) of the moss plant. *The stalk and capsule together form the sporophyte* (spō′rō-fīt) *or spore-producing generation of the moss.*

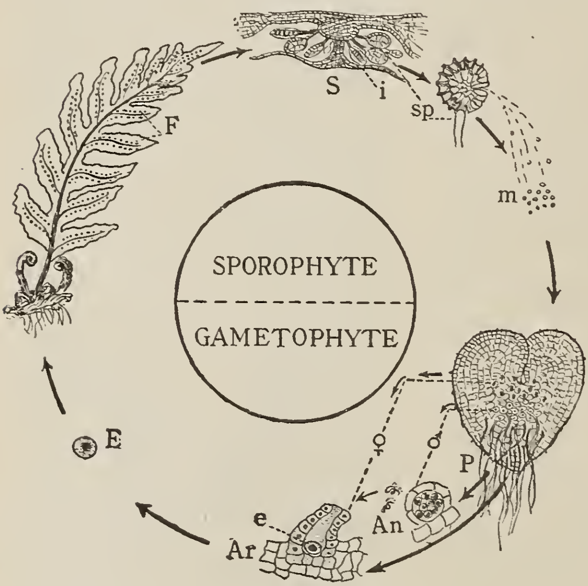


Two moss plants, showing the gametophyte *G* and the sporophyte *S*.

*Gametophyte.* — The spore germinates into a threadlike structure, called a *protone′ma.* The protonema soon develops rhizoids; tiny buds appear which in time form the adult moss plants. These plants may grow only leaves, or they may develop into plants that bear at the summit a little rosette of leaves within which lie a number of tiny organs holding sperm cells. Other moss plants not so tall as the sperm-producing plants bear at the summit of the stem a tuft of leaves which hide a number of small flask-shaped structures, each of which contains a single egg cell. *These two kinds of plants form the sexual generation of the moss. This stage of the plant is called the gametophyte* (ga-mē′tō-fīt) *because it produces the gametes or sexual cells, — eggs and sperms.* After a sperm cell has been transferred (usually by means of a drop of dew) to the egg cell, a fusion of the two cells takes place. This is the process of *fertilization.* The fertilization of the egg cell results in the growth of that part of the plant which forms and bears the *asexual* spores, the stalk and capsule, or *sporophyte.* These spores give rise in turn to a leafy moss plant which bears organs producing eggs and sperms. This process of reproduction by two alternating stages is known as *alternation of generations.*

**The Ferns and their Allies.** — This group of plants is of much more importance in tropical countries, where many more forms are found than here. They are chiefly interesting to us in our elementary study because they, like the mosses, show *alternation of generations* in their life history.

**Life History of a Fern.** — The common fern of our woods begins life as a spore. This germinates into a tiny heart-shaped body called a *prothal'lus* which contains *sex* organs holding sperm and egg cells. These cells after fertilization produce leafy structures (*fronds*) which bear the *asexual* spores. These spores when ripe germinate in the ground and the life cycle begins over again, a sexual generation alternating with an asexual generation.




Alternation of generations in the fern: The fronds *F* produce groups of spore cases *s* called sori. Each sorus is sometimes covered by an indusium *i*. A sorus is made up of sporangia *sp*, and each sporangium forms spores *m*. A spore may germinate under favorable conditions to form a tiny prothallus *P*. This in turn forms two kinds of organs, antheridia *An*, bearing sperms, and archegonia *Ar*, bearing egg cells *e*. As a result of the union of an egg and a sperm cell *E*, the adult fern plant is formed.

It may be said that the ferns as a group have formed a large part of the enormous deposits of coal (almost pure carbon) from which we now derive the energy to run our many engines.

**Sexual Reproduction in Flowering Plants.** — Flowering plants reproduce their kind by the formation of seeds. As we know, the flower produces in the ovary structures which are called *ovules*. In the interior of the ovule is found a clear protoplasmic area which is called the *embryo sac.* In this area is a cell (the egg cell) which is destined to form the future plant. In the pollen grain is found another cell, the *sperm*. This cell,

after the germination of the pollen grain on the stigma of the flower, passes through the pollen tube, enters the ovule, and unites with the egg cell. The fertilized egg grows into the young plant within the seed, known as the embryo (see pages 25–27). This method of reproduction, called *sexual* reproduction, is found in the *spermat'ophytes*, that is, all seed-producing plants.

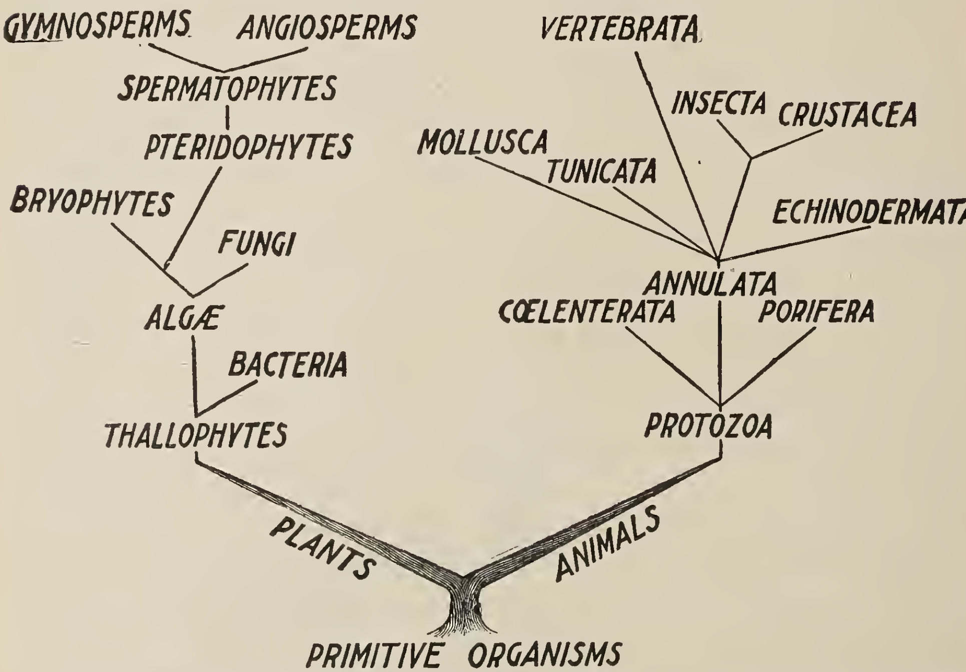
Botanists have shown that in the spermatophytes there exists an alternation of generations as in the mosses and ferns. The pollen grain is believed to be a spore, which develops into the male gametophyte (the pollen tube), while the embryo sac is another spore, within which is found the female gametophyte Most of the life of the flowering plant is thus passed evidently in the asexual or sporophyte stage. All plants — and all animals as well — form the cells which compose their bodies by either sexual or asexual growth, and the stage of asexual growth is usually separated from the period of sexual growth.

**Systematic Botany.** — The plant world is divided into many tribes or groups. Not only are plants placed in large groups each having a few very conspicuous characteristics in common, but smaller groupings have been made, each containing only a few plants having many characteristics in common. If we plant a number of peas so that they will all germinate under the same conditions of soil, temperature, and sunlight, the seedlings that develop will differ one from another in a slight degree. But in a general way they will have many characteristics in common, as the shape of the leaves, the possession of tendrils, and the form of the flower and fruit. *The smallest group of plants or animals having certain characteristics in common that make them different from all other plants or animals is called a species.* Individuals of a species differ slightly; for no two individuals are exactly alike.

A number of species are combined in a larger group called a *genus* (jē'nus). For example, many kinds of peas — the garden peas, the wild beach peas, the sweet peas, and many others — are all grouped in one genus because they have certain structural characteristics in common.

Plant and animal genera are brought together in still larger groups, the classification based on general likenesses in struc-

ture. Such groups are called, as they become successively larger, Family, Order, and Class. Thus the plant and animal kingdoms are grouped into divisions, the smallest of which contains individuals very much alike; and the largest of which contains very many groups of individuals, each group having some characteristics in common. This is called a system of classification.




Tree of life. There is little difference between the lowest forms of plant and animal life, but much difference between the highest plants (Angiosperms) and the highest animals (Vertebrata).

**Classification of the Plant Kingdom.** — The entire plant kingdom has been grouped as follows by botanists:

1. *Spermatophytes.*
   - *Angiosperms* (ăn′jĭ-ō-spermz), true flowering plants.
   - *Gymnosperms* (jĭm′nō-spermz), the pines and their allies.
2. *Pteridophytes* (tĕr′ĭ-dō-fīts). The fern plants and their allies.
3. *Bry′ophytes.* Moss plants and their allies.
4. *Thallophytes.*
   - *Algæ,* simple plants containing chlorophyll.
   - *Fungi,* simple plants without chlorophyll.

The extent of the plant kingdom can only be estimated, because each year new species are added to the lists. There are

about 110,000 species of flowering plants and nearly as many flowerless plants. The latter consist of over 3500 species of fernlike plants, some 16,500 species of mosses, over 5600 lichens (lī′kĕnz) — plants consisting of a partnership between algæ and fungi, — approximately 55,000 species of fungi, and about 16,000 species of algæ. Some botanists regard bacteria as fungi, while others make them a separate branch of thallophytes, as indicated in the diagram on page 134.

**Summary.** — We have seen in this chapter that the diverse forms of plants on the earth may be grouped into four great divisions, the *Thallophytes* or very simple plants having a thallus body, the *Bryophytes* or mosses, *Pteridophytes* or ferns, and *Spermatophytes* or seed-producing plants.

The environment has doubtless played a very important part in producing the various forms of plants, for botanists believe that many millions of years ago the earth was covered with a very much simpler vegetation than it is at present. Plants have been forced to adapt themselves to new conditions in order to live and varying conditions of environment have resulted in developing the different kinds of plants now existing.

**Problem Questions.** — 1. How do changes in environment cause changes in plant structure?

2. Why are the algæ believed to be the first plants to inhabit the earth?

3. How are algæ of use to man?

4. How can you distinguish a fungus? a moss? a fern?

5. What is meant by *alternation of generations?*

6. What is a species?

7. What is meant by a system of classification?

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# XII. HOW PLANTS ARE MODIFIED BY THEIR SURROUNDINGS

***Problem.*** *To discover how plants are modified by their surroundings.* (*Optional.*) (*Laboratory Manual, Prob. XXI.*)

(*a*) *Hydrophytic society.*
(*b*) *Xerophytic society.*
(*c*) *Mesophytic society.*
(*d*) *Plant societies.*
(*e*) *Plant zonation.*

**The Way in which Plants are modified by their Surroundings.** — As we have found in our experiments, young plants are delicate organisms, which are affected profoundly by the action of forces outside themselves. The same is true to a certain extent of older plants. The presence or absence of moisture starts or prevents growth in seeds or young plants; absence of light changes the form and color of green plants; and favorable temperature, which varies for different plants, influences the growth. Pea seedlings may grow for a time in sawdust, but we know that they will be much healthier and will live longer if placed in soil under natural conditions. We are forced to the conclusion that differences in the forms and habits of plants are caused by the action of their surroundings upon them. The plants which have become in various ways fitted to live under certain conditions are said to be *adapted* to such conditions. Such plants as are best fitted to

Pond lilies, plants with floating leaves. Photograph by W. C. Barbour.

live under the conditions in which they are placed are the ones which will survive.

A water plant, showing the finely divided leaflike parts.

**Water Supply.** — Water supply is one of the important factors in causing changes in structure of plants. Plants which live entirely in the water often have slender parts with finely divided leaves. Their roots are apt to be short and stout. The interior of such a plant is made up of spongy tissues which allow the air dissolved in the water in which they live to reach all parts of the plant. If the plant has floating leaves, as in the pond lily, the stomata are all in the upper side of the leaf.

**Hydrophytes.** — When a plant lives in water or in soil saturated with water, the conditions of its environment are said to be *hydrophyt'ic*, and such plant is said to be a *hydrophyte* (hī'drŏ-fīt).

**Xerophytes.** — If we examine plants growing in dry or desert

A xerophytic condition. Cacti and other plants in a desert. Photograph from American Museum of Natural History.

conditions, as cactus, sagebrush, aloe, etc., we find that the leaf surface is invariably reduced, sometimes forming spines as in the cactus. The stem may be thickened so as to store water; a covering of hairs or some other material may be present and lessen the loss of moisture by evaporation. The conditions of extreme dryness under which such plants live are called *xerophytic* (zē-rō-fĭt′ĭk), and such plants are known as *xerophytes* (zē′rō-fīts). Examples of xerophytes are the cacti, yuccas, century plants, etc.

**Halophytes.** — If the water or saturated soil in which the plant lives contains salts, such as sea salt or the alkali salts of

A mesophytic condition. A valley in central New York.

some of our Western lakes, the conditions are said to be *halophyt′ic,* and a plant living under such conditions is known as a *hal′ophyte.* Halophytes show many characteristics which xerophytes show.

**Mesophytes.** — Most plants in the Temperate Zone occupy a place midway between the xerophytes on one hand and hydrophytes on the other. They are plants which require a moderate amount of water in the soil and air surrounding them. Such are most of our forest and fruit trees. and most of our gar-

den vegetables. Conditions of moderate moisture are called *mesophytic;* the plants living under such conditions are known as *mesophytes* (mĕs′ŏ-fīts).

**Other Factors.** — It is a matter of common knowledge that plants in different regions of the earth differ greatly from one another in shape, size, and general appearance. If we study the causes for these changes, it becomes evident that the water supply is one of the most important factors, whether in the

The effect of wind upon trees in an exposed location. Photograph by W. C. Barbour.

tropics or arctic regions. But in addition to water supply, the factors of temperature, light, soil, wind, etc., all play important parts in determining the form and structure of a plant.

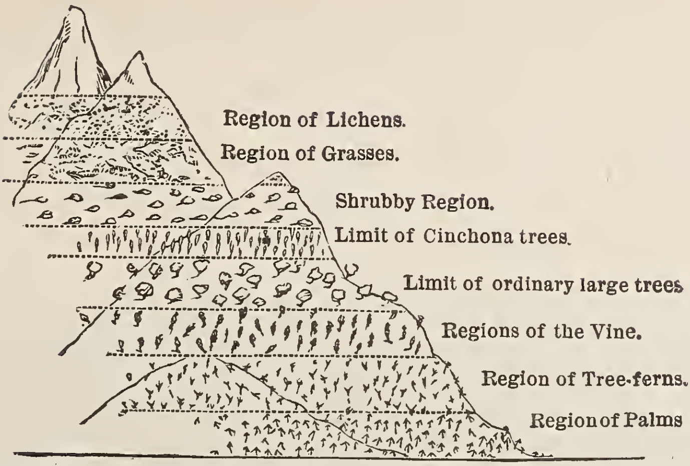
**Cold Regions.** — Here plants, which in lowland regions of greater warmth and moisture have a tall form and luxuriant foliage, are stunted and dwarfed; their leaves are small and tend to gather in rosettes, or are otherwise closely placed for warmth and protection. As we climb a mountain we find that the average size of plants decreases as we approach the line of

perpetual snow. The largest trees occur at the base of the mountain; the same species of trees near the summit appear as mere shrubs. Continued cold and high winds are evidently the factors which influence the slow growth and the small size and shape of plants near the mountain tops. Cold, little light during the short days of the long winter, and a slight amount of moisture all act upon the vegetation of the arctic region,

Polar limit of trees, northern Russia. All these trees are full grown, and most of them are almost one hundred years old.

and tend to produce very slow growth and dwarfed and stunted forms.

**Vegetation of the Tropics.** — A rank and luxuriant growth is found in tropical countries with a uniformly high temperature and large rainfall. In general it may be estimated that the rainfall in such countries is at least twice as great as that of New York state, and in many cases three to four times as great. An abundant water supply, together with an average temperature of over 80° Fahrenheit, causes extremely rapid growth. One of the bamboo family, the growth of which was measured daily, was found to increase in length on the average nearly three inches in the daytime and over five inches during each night. The moisture present in the atmosphere allows the




Plant regions in a tropical mountain. Explain the diagram.

growth of many air plants (*ep'iphytes*), which take the moisture directly from the air by means of aërial roots.

The absence of cold weather in tropical countries allows trees to mature without a thick coating of bark or corky material,

Conditions in a moist, semitropical forest. The so-called "Florida moss" is a flowering plant. Notice the resurrection ferns on the tree trunk.

and so they have a green and fresh appearance. Monocotyledonous plants prevail. Ferns of all varieties, especially the largest tree ferns, are abundant.

**Plant Life in the Temperate Zones.** — In the state of New York, conditions are those of a typical temperate flora. Extremes of cold and heat are found, the temperature ranging from 30° below zero Fahrenheit in the winter to 100° or over

Plant societies near a pond. Notice that the plant groups are arranged in zones with reference to the water supply, the true mesophytes being in the background.

in the summer. Conditions of moisture show an average rainfall of from 24 inches to 52 inches.

In the eastern part of the United States the rainfall is sufficient to supply very extensive forests, which aid in keeping the water in the soil. In the Middle West the rainfall is less, the prairies are covered with grasses and other plants which have become adapted to withstand dryness. In the desert region of the Southwest we find true xerophytes, cacti, yuccas, and others, plants which are adapted to withstand almost total absence of moisture for long periods. In the Temperate Zone as elsewhere the water supply is the primary factor which determines the form of plant growth.

**Plant Formations and Societies.** — All of the factors referred to act upon the plants we find living together in a forest, a sunny meadow, along a roadside, or at the edge of a pond. Any one familiar with the country knows instinctively that we find certain plants, and those plants *only*, living together under certain conditions.

Plants associated under similar conditions, as those of a forest, meadow, or swamp, are said to make up a *formation*,

A rock society. Photograph by W. C. Barbour.

and a plant formation is brought about by the conditions of the immediate surroundings, the habitat of its members. If we investigate a plant formation, we find it to be made up of certain dominant species of plants; that here and there definite communities exist, made up of groups of the same kind of plants. We can see that each one of these plant groups in the society evidently came originally from a single individual which flourished under the peculiar conditions of soil, water, light, etc., that were found in this spot. These single plants have evidently given rise to the members in each little family group, and thus have populated the locality.

So we find among plants communal conditions similar to those of some animals. The many individuals of the com-

munity live under similar conditions; they need the same substances from the air, the water, the soil. They all need the light; they use the same food. Therefore there must be competition among them, especially between those near to each other. The plants which are strongest and best fitted to get what they need from their surroundings, live; the weaker ones are crowded out and die.

But their lives are not all competition. The dead plants and animals give nitrogenous material to the living ones, from which the latter make living matter; some bacteria provide certain of the green plants with nitrogen; many of the green plants make food for other plants lacking chlorophyll, while some algæ and fungi actually live together in such a way as to be of mutual benefit to each other. The larger plants may shelter the smaller ones, protecting them from wind and storm, while the trees provide humus which holds the moisture in the ground, giving it off slowly to other plants. Animals scatter and plant seeds far and wide, and man may even start entire colonies in new localities.

A community of trilliums. Photograph by W. C. Barbour.

**How Plants invade New Areas.** — New areas are tenanted by plants in a similar manner. After the burning over of a forest, we find a new generation of plants springing up, often quite unlike the former occupants of the soil. First come the fireweed and other light-loving weeds, brought by means of their wind-blown seeds. With these are found patches of berries, the seeds of which were brought by birds or other animals. A little later, quick-growing trees having seeds easily carried for some distance by the wind, like the aspen, or seeds often distributed by birds, as the wild cherry, invade the territory. Eventually we may have the area retenanted by the same

kind of inhabitants as formerly, especially if the destruction of the original forest was not complete.

In like manner, on the upper mountain meadows or by the sand dunes of the seashore, wherever plants place their outposts, the advance is made from some thickly inhabited area, and this advance is always aided or hindered by agencies

A plant outpost. The struggle here is keen. The advancing sand has killed the trees in the foreground.

outside of the plant — the wind, the soil, water, or animals. Thus the seeds obtain a foothold in new territory, and new lands are captured, held, and lost again by the plant communities.

**Summary.** — Plants are so modified by the factors of their environment that they may take various forms and have many kinds of devices to enable them to cope with the unfavorable factors in their environment. Water plays a most important part in modifying their form and structure. Plants are grouped according to water supply, into xerophytic or drought-loving plants, hydrophytic or water-loving plants, and mesophytic plants or those which need a moderate supply of moisture. Different species of plants are usually found in definite associations or groups. This grouping is brought about by the need of similar environmental conditions by different kinds of plants.

**Problem Questions.** — 1. Why do plants vary in different localities?

2. What are the chief structural differences between hydrophytes, xerophytes, and mesophytes?

3. What are the characteristics of tropical plants? of those from cold regions?

4. How might a new outpost of plant life be established?

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# XIII. HOW PLANTS BENEFIT AND HARM MANKIND

**Problem.** *To determine how fungi help or harm mankind. (Laboratory Manual, Prob. XXII; Laboratory Problems, Probs. 87 to 94.)*

(*a*) *Yeast.*
(*b*) *Mold.*
(*c*) *Other fungi.*

**The Economic Value of Plants.** — Besides the other relations existing between plants and animals, there is a relation between man and plants measurable in dollars and cents. Plants are of direct value or harm to man. We call this an economic relation. We have seen how they supply him with his cereals and flour, his fruits and garden vegetables, his nuts and spices, his beverages and the sugar to sweeten them, his medicines and his dyestuffs. They supply the material out of which many of his clothes are made, the thread with which they are sewed together, the paper which covers the package in which they are delivered, and the string with which the package is tied. The various uses of the forest have been mentioned before; the need of trees to protect the earth, their usefulness in regulating the water supply, and their direct economic importance for lumber and firewood. Many of us forget, too, that much of the energy released on this earth to man as heat, light, or motive power comes from the dead and compressed bodies of plants which thousands of years ago lived on the earth and now form coal. Plants are thus seen to be of immense direct economic importance to mankind.

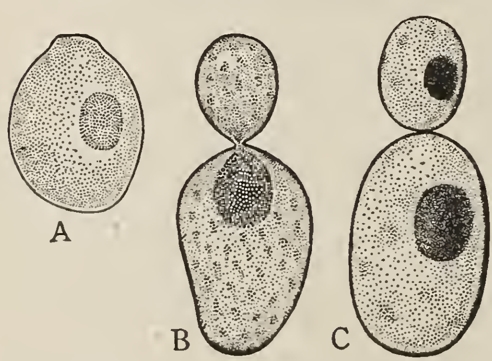
**The Harm Plants Do.** — Unfortunately, plants do not all benefit mankind. We have seen the harm done by weeds, which scatter their numerous seeds far and wide or by other devices gain a foothold and preëmpt the territory which useful plants might occupy were they able to cope with their better-

equipped adversaries. Plants with poisonous seeds and fruits are undoubtedly responsible for the death of many animals and of man as well.

But the plants by far the most harmful to mankind are the fungi. Damage to the amount of hundreds of millions of dollars a year may be laid directly to them. More than that, if we include the tiny organisms called bacteria they are responsible for over one half of the total human deaths, because of their parasitic habits.

**Yeast.** — Although as a group the fungi are harmful to man in the economic sense, nevertheless there are some fungi that stand in a decidedly helpful relationship to the human race. Chief of these are the yeast plants. Yeasts are found to exist in a wild state in very many parts of the world. They are found on the skins of apples, grapes, and other fruits, and they may exist in a dry state almost anywhere in the air around us. In a cultivated state we find them as the agents which cause the rising of bread, and the fermentation in beer and other alcoholic fluids.

**Yeast Plants.** — The common compressed yeast cake contains millions of these tiny plants. In its simplest form a yeast plant is a single cell. If you shake up a bit of a compressed yeast cake in a mixture of molasses and water and then examine a drop of the milky fluid after it has stood over night, it will be seen to contain vast numbers of yeast plants. The plants are tiny ovoid cells from $\frac{1}{2500}$ to $\frac{1}{10,000}$ of an inch in diameter. The protoplasm is granular and contains no chlorophyll. The cells grow by means of budding, the parent cell forming one or more daughter cells somewhat smaller than the original cell and attached to it (see Figure). Sometimes yeast cells form spores, although we rarely see them in the laboratory.



Budding yeast plants stained to show nucleus, highly magnified.

**Conditions Favorable to Growth of Yeast.** — Under certain conditions yeast, when added to dough, will cause it to rise. We know also that yeast has something to do with the process of fermentation. The following home experiment will throw some light on these points:

Label three pint fruit jars A, B, and C. Add one fourth of a compressed yeast cake to two cups of water containing two tablespoonfuls of molasses. Stir the mixture well, divide it into three equal parts, and pour one part into each jar. Place covers on the jars. Put jar A in the ice box on the ice, and jar B over the kitchen stove or near a radiator; heat jar C by immersing it in a dish of boiling water, and place it next to B. After forty-eight hours, look to see if any bubbles have made their appearance in any of the jars. If the experiment has been successful only jar B will show bubbles. After bubbles have begun to appear at the surface, the fluid in jar B will be found to have a sour taste and will smell unpleasantly. The gas which rises to the surface, if collected and tested, will be found to be carbon dioxide. The contents of jar B are said to have fermented. Evidently, the growth of yeast will take place under conditions of moderate warmth and moisture and in the presence of food.

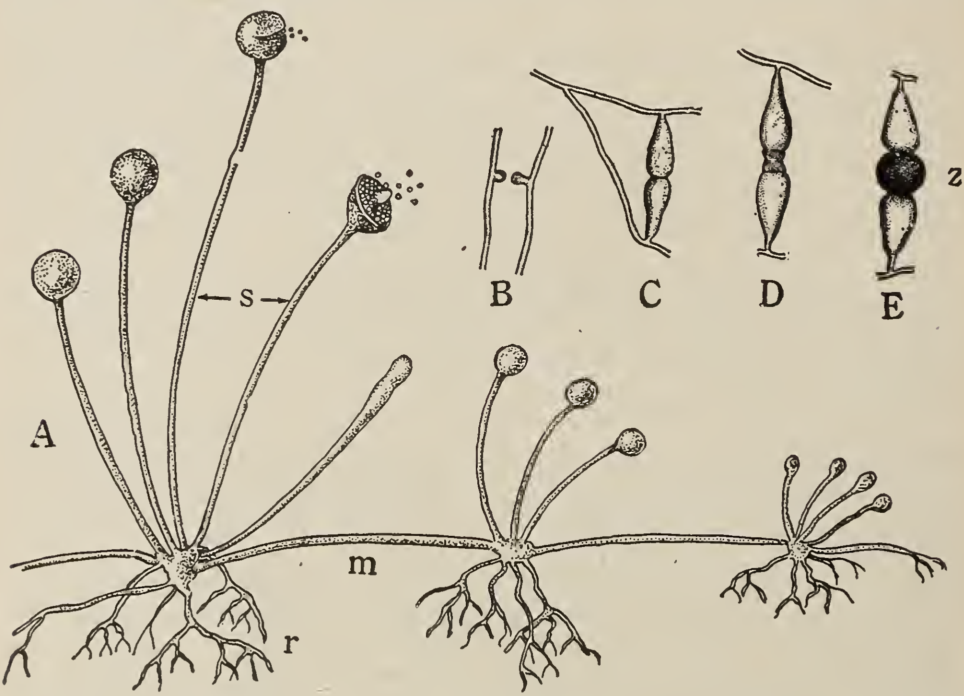
**Fermentation a Chemical Process.** — In the growth of yeast cells the sugar of the solution in which they live is broken up by an enzyme into carbon dioxide and alcohol. This may be expressed by the following chemical formula: $C_6H_{12}O_6 = 2(C_2H_6O) + 2(CO_2)$. This means that the sugar acted upon by the enzyme in the yeast cell, is made into alcohol and carbon dioxide. This process is called fermentation.

When bread dough is expected to "raise" it is put in a warm place so that the yeast plants in the dough will grow rapidly. They feed upon starch, which they digest into grape sugar. Fermentation results from the rapid growth, causing the bubbles of carbon dioxide in the dough. When the bread is baked the spaces which were filled with carbon dioxide remain while the alcohol is evaporated in the baking.

**The Yeast Plant a Saprophyte.** — Since yeast grows upon dead organic material it is a *saprophyte*. Saprophytic plants are frequently seen in our homes and some do much damage. Bread mold is an example.

**Mold.** — This is one of our most common fungi. It grows upon bread, cake, and other organic substances under certain conditions of temperature and moisture.

We are all familiar with the tangled mass of tiny whitish threads which are sometimes found growing over damp bread. The mass of threads is called collectively the *mycelium* (mī-sē′lĭ-um), each thread being called a *hypha* (hī′fa). Many of the hyphæ are prolonged into tiny, upright threads, bearing a little ball at the top. With the low power microscope each of these structures is seen to contain many




Stages in reproduction of mold: *A*, vegetative form, showing the rootlike rhizoids *r*, the mycelium *m*, and the spore-bearing bodies *s*, in three stages of growth; *B* to *E*, stages in conjugation, resulting in the formation of a zygospore *z*.

tiny bodies called *spores*. These spores have been formed by the division of the protoplasm within the ball or *sporangium* into many separate bodies or asexual spores. These spores, if grown under favorable conditions, will produce more mycelia, which in turn bear sporangia. The mold, however, like *spirogyra*, can produce *zygospores* under certain conditions. These are probably sexual spores and are evidently of use to continue the life of the plant during unfavorable conditions.

**Physiology of the Growth of Mold.** — Mold, in order to grow rapidly, evidently needs oxygen, moisture, and a favorable tem-

perature. The mold sends down into the bread rootlike processes. These branching hyphæ pass out through their walls digestive enzymes, which change the starches and proteins of the bread to soluble substances which are taken in through the walls of the hyphæ by osmosis. Thus a mold digests its food outside of the body and then absorbs it. These foods are then used to supply energy and to make protoplasm. This seems to be the usual method by which saprophytes secure the materials on which they live.

**Other Saprophytic Fungi: Mushrooms.** — Some of the best known of the fungi are the mushrooms or "toadstools" as they are often called. What we see is the temporary spore-bearing part, the mycelium being below ground. The mushrooms live upon decaying plant or animal material, which they digest and absorb by means of their rootlike hyphæ. Care and good judgment are needed in distinguishing the harmful from the edible mushrooms, although it is not hard to learn some of the edible fungi of a locality. Why not make this a project to work out? Excellent books of reference on this subject are Marshall's *The Mushroom Book*, Doubleday, Page and Company, and Atkinson's *Mushrooms*, Henry Holt and Company.

Mushrooms; the younger specimen, at the right, shows some of the mycelium. Photographed by Overton.

**The Shelf Fungus.** — This is a near relative of the mushroom. The "bracket" found growing on dead tree trunks is the spore case, while the mycelium is within the tissue of the tree. Remove the bark from a tree infected with a bracket fungus, and you will find the silvery threads of the mycelium sending their greedy hyphæ to all parts of the wood adjacent

to the spot first attacked by the fungus. This fungus begins its life by the lodgment of a spore in some part of the tree which has become *diseased* or *broken*. Once established on its host, it spreads rapidly. Each year many fine trees, sound except for a slight bruise or other injury, are infected and eventually killed. In cities thousands of trees become infected where horses have been hitched carelessly so that they could gnaw or crib on the tree, thus exposing a fresh surface on which spores may obtain lodgment and grow (see page 123). There is no remedy except to burn the infected trees, so as to destroy the spores.

**Suggestions for Field Work.** — A field trip to a park or grove near home may show the great destruction of timber by this means. Count the number of perfect trees in a given area. Compare it with the number of trees attacked by the fungus. Does the fungus appear to be transmitted from one tree to another near at hand? In how many instances can you discover the point where the fungus first attacked the tree? How do the spores leave the sporecase? How do they germinate on the tree attacked?

**Parasitic Fungi.** — Of even more importance are the fungi that attack a living host, true parasites. The most important of such plants from an economic standpoint are the rusts, smuts, and mildews which prey upon grain, corn, and other cultivated plants. Some fungi are also parasitic upon fruit and shade trees. The chestnut canker, a fungus introduced from abroad on chestnuts planted near the city of New York in 1904, had during ten years destroyed practically every chestnut tree within a radius of 150 miles. At the present time the disease is spreading rapidly and may eventually destroy all of the native chestnuts in the United States unless drastic methods of combating the pest are used. Hundreds of millions of dollars' damage has already been done and more will follow. The pine tree blister rust introduced from Europe about 1909 threatens the existence of nearly $500,000,000 of timber.

**Wheat Rust.** — Wheat rust is probably the most destructive parasitic fungus. For hundreds of years this rust has been the most dreaded of plant diseases, because it destroys the one harvest upon which the civilized world is most dependent. For a long time past the appearance of rust has been associated with

the presence of barberry bushes in the neighborhood of the wheat fields. Although laws were enacted in 1760 in New England to provide for the destruction of barberry bushes near infected wheat fields, nothing was actually known of the relation existing between the rust and the barberry until comparatively recent years. It has now been proved beyond doubt that the wheat rust passes part of its life as a parasite on the barberry and from it gets to the wheat plant, where it undergoes a complicated life history. The wheat leaf, its nourishment and living matter used as food by the parasite, soon dies, and no grain is produced. Some wheat rusts appear to have other intermediate hosts than the barberry, so that the problem of fighting this plant enemy has been much more difficult than if all the facts about it were known.

**Sac Fungi.** — Another group of fungi that are of considerable economic importance is made up of the sac fungi. Some of these fungi are called mildews. Some of the most easily obtained specimens come from the lilac, rose, or willow. These fungi do not penetrate the host plant to any depth, but cover the leaves of the host with the whitish threads of the mycelium. Hence they may be killed by means of applications of some fungus-killing fluid, as Bordeaux mixture. They obtain their food from the outer layer of cells in the leaf of the host. Among the useful plants preyed upon by this group of fungi are the plum, cherry, and peach trees. The diseases known as black knot and peach curl are thus caused.

***Problem.*** *A study of bacteria in order to determine —*

(*a*) *Their conditions of growth.*

(*b*) *Some of their relations to man.*

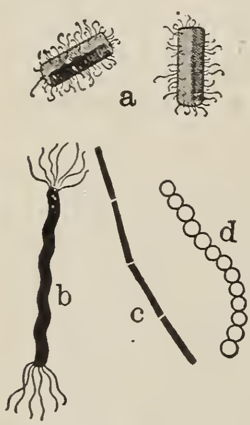
(*c*) *Methods of fighting harmful bacteria.*

(*Laboratory Manual, Prob. XXIII; Laboratory Problems, Probs. 95 to 103.*)

**Bacteria.** — The bacteria are found in the earth, the water, and the air: "anywhere but not everywhere," as one writer has put it. They swarm in stale milk, in impure water, in the living bodies of plants and animals, and in any decaying material. These tiny plants, "man's invisible friends and foes,"

are of such importance to mankind that thousands of scientists devote their whole lives to the study of *bacteriology.*

**How Bacteria were Discovered.** — As early as 1683 the Dutchman Leeuwenhoek is believed to have seen bacteria with his newly invented microscope. But it was not until 1865 that Louis Pasteur, the famous Frenchman, discovered the relation between bacteria and disease. Pasteur had shortly before this proved that bacteria caused fermentation and that when floating germs got into nutrient fluids such fluids would "go bad" and would decay. Pasteur laid the foundation for the study of disease germs and his name should be remembered, not alone for his discovery of a cure for hydrophobia but because he was the first man to attempt to manufacture antitoxin serums and vaccines to fight the poisons produced by disease. Robert Koch is another man who helped to make bacteriology an important science. We remember him in particular as the discoverer of the germ causing tuberculosis.

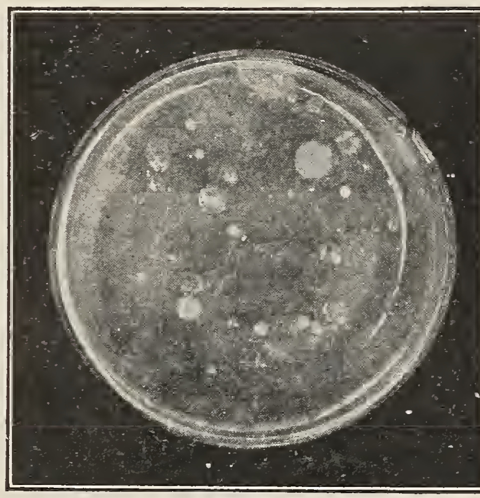


Bacteria, highly magnified: *a*, the germ of typhoid fever, stained to show the cilia, little threads of living matter by means of which locomotion is accomplished; *b*, a spiral form with flagella, tiny threads longer than cilia; *c*, a rod-shaped form, in a chain; *d*, a spherical form.

**Size and Form.** — Bacteria are the most minute organisms known. A bacterium of average size is about $\frac{1}{5000}$ of an inch in length, and perhaps $\frac{1}{25,000}$ of an inch in diameter. Some species are much larger, others smaller. A common spherical form is $\frac{1}{50,000}$ of an inch in diameter. It will mean more to us, perhaps, if we realize that 1000 bacteria of average size might be placed on the dot of this letter *i*. Three well-defined forms of bacteria are recognized: a spherical form called a *coc′cus;* a rod-shaped bacterium, the *bacillus* (ba-sĭl′us); and a spiral form, the *spiril′lum.* Some bacteria are capable of movement when living in a fluid. Such movement seems to be caused by tiny threads of protoplasm called *cilia* or *flagella,* which project from the body and vibrate rapidly. Bacteria reproduce with almost incredible rapidity. A single bacterium, by simple fission or splitting, will in twelve hours give rise to almost

17,000,000 offspring if each divides only once every half hour. It has been estimated that if a bacterium could go on multiplying unchecked for five days, it would fill all the oceans of the earth to a depth of one mile. But of course nothing of the kind ever happens because of the many unfavorable conditions which exist. Under unfavorable conditions bacteria die or at least stop dividing and form spores, in which state they remain until conditions of temperature and moisture are such that growth may begin again.

**Method of Study.** — In order to get a group of bacteria of a given kind to study, it becomes necessary first to *catch* them. This is easily done by exposing to the air a shallow dish — known as a Petri (pĕt′re) dish — containing a culture medium on which bacteria will grow. The medium is made by cooking beef broth and either gelatine or agar-agar together for a few moments. The culture medium is poured into a sterilized Petri dish while it is still hot and the cover is placed over it quickly so that the contents of the dish will remain sterile or free from all life until the cover is removed. If after a short exposure to the air of the schoolroom the dish is covered and put away in a warm place for a day or two, little spots will appear on the surface of the culture medium.



A Petri dish culture of bacteria; the colonies of bacteria are little spots of various sizes and colors.

**Pure Culture.** — The spots are colonies composed of millions of bacteria. If now we wish to study one given form, it becomes necessary to isolate it from the others in the dish. This is done by the following process: a platinum needle is first passed through a flame to *sterilize* it; that is, to kill all living things that may be on the needle point. Then the needle, which cools very quickly, is dipped in a colony containing the kind of bac-

teria we wish to study. This mass of bacteria is quickly transferred to another sterilized Petri dish containing culture medium, and covered to prevent any other forms of bacteria from entering. The dish is then placed in a warm oven for a night in order to get a good growth of bacteria. When we have succeeded in isolating a certain kind of bacteria in a given dish, that is, when colonies of only one kind are present, we have a pure culture.

**Conditions Favorable and Unfavorable for Growth of Bacteria.** — *Temperature.* Like most living things, bacteria grow most rapidly in a favorable temperature. While this is usually about body temperature or 98.6° Fahrenheit, it is sometimes lower. We may say that at this favorable temperature bacteria have the most rapid growth. Conversely, cold retards their growth, as does extreme heat. Freezing will stop their growth altogether, although it does not kill the more hardy forms. Heating to 150° to 160° Fahrenheit will, if continued for at least thirty minutes, destroy bacteria with the exception of those in the spore stage. These may resist boiling for some time. In order to make absolutely sure that all spores are killed, the bacteriologist raises the material which contains them to boiling for a second or even a third time, with a period of several hours intervening in each case. This is known as *discontinuous sterilization.*

*Moisture.* Bacteria require considerable moisture in order to *grow*, although they may be found in an inactive state in dry localities. Household foods, therefore, if in a dry condition, will not be spoiled by bacteria, a fact worth remembering.

*Light.* We find that if a Petri dish containing growing bacteria is exposed to a strong light the growth will be retarded or stopped completely. Sunlight kills many kinds of bacteria. This fact has been made use of in the fight against various disease-producing bacteria, especially those which produce tuberculosis. A sickroom should therefore be flooded with sunlight whenever possible, and should be provided with furniture and hangings that can easily be cleaned and aired.

*Air.* Although bacteria need oxygen in order to live, as do all living things, some kinds thrive in the absence of air, ob-

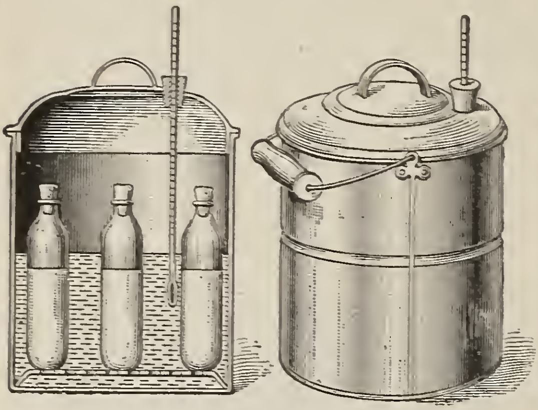
taining the oxygen necessary for oxidation by breaking down the substances on which they feed, thus releasing oxygen. Such bacteria are called *anaërobic* (ăn-ā-ẽr-ŏb′ĭk). Most of the bacteria found in daily life live in the air and are called *aërobic.*

**Bacteria cause Decay.** — Bacteria affect mankind in many ways, either directly or indirectly. First of all, they cause decay. All organic matter, in whatever form, is sooner or later decomposed by the action of untold millions of bacteria which live upon organic matter in water and soil. These bacteria, therefore, are useful because they feed upon the dead bodies of plants or animals, which otherwise would soon cover the surface of the earth to the exclusion of everything else. Bacteria may thus be considered scavengers. Without bacteria and a few of the fungi, life on the earth would be impossible, for green plants would be unable to get the raw materials in forms that they could use in making food and new living matter. In this respect bacteria are of the greatest service to mankind.

Tubercles or nodules (little lumps) on the roots of soy bean, containing nitrogen-fixing bacteria.

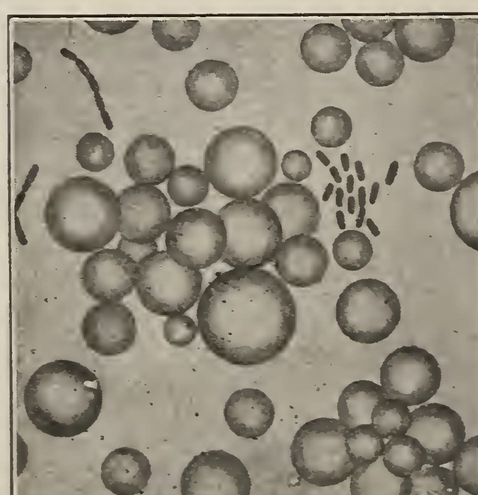
When bacteria grow in sufficient numbers upon foods, meat, fish, or vegetables, they spoil them, and may form poisonous substances called *ptomaines* (tō′-mā̆-ĭnz) by their action on protein. As the result of eating food containing these ptomaine poisons, one may become violently ill. Fish and meats that have been kept for some time in cold storage are very easily spoiled, and should be avoided. Canned goods that have "worked," that is, those in which yeasts or bacteria have caused fermentation and decay, are unfit for food.

**Nitrogen-fixing Bacteria.** — Certain bacteria, in the process of decay, "change over" nitrogen in organic material in the soil so that it can be used by plants in the form of a compound of nitrogen. But the bacteria living in tubercles on the roots of clover, beans, peas, etc., have the power of "fixing" the free nitrogen in the air found between particles of soil so that it may be absorbed as a nitrate by the root hair. This fact is made use of by farmers who rotate their crops, growing first a crop of clover or alfalfa, which produce the bacteria, then plowing these up and planting another crop, as wheat or corn, on the same area. The latter plants, making use of the nitrogen compounds there, produce a larger crop than when grown in ground containing less nitrogenous material.



A pasteurizing apparatus.

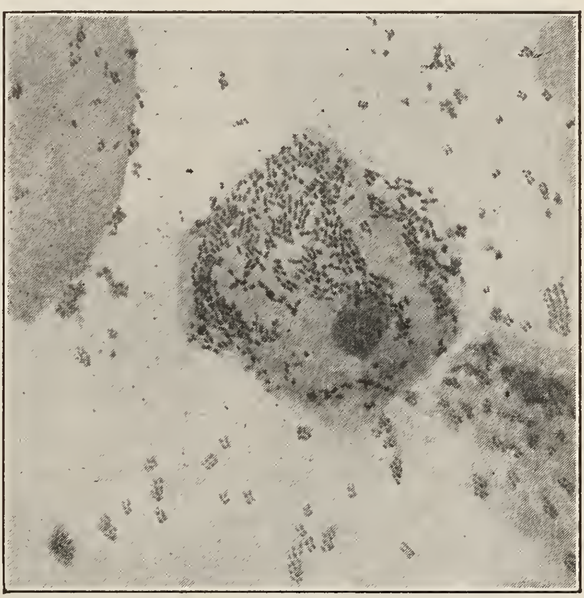
**Other Processes caused by Bacteria.** — Bacteria may incidentally, as a result of the process of decay, aid in the process of fermentation. In making vinegar the yeasts first make alcohol (see page 149), which the bacteria later change to acetic acid. In milk there are many kinds of bacteria, some of which act upon the milk sugar, changing it to an acid, and thus causing the milk to sour. The lactic acid bacteria grow very rapidly in a warm temperature; hence milk which is kept iced does not sour readily. Pasteurized milk (that is, milk that has



Microscopic appearance of ordinary milk, showing fat globules and bacteria. The cluster of bacteria on the right side are germs that form lactic acid. Tuberculosis germs are sometimes found in milk.

been heated to a temperature of about 145° Fahrenheit for 20 or 30 minutes) remains sweet for some time also if kept in a cool place. Why? The same lactic acid bacteria may be useful when they sour the milk for the cheese-maker. Certain other bacteria give flavors to cheese and butter, while still others are used by the tanner in the preparation of leather. The "retting" of flax, or the rotting away of the non-usable tissues of the flax stem, is due to the action of bacteria. Sponges are prepared for the market by bacteria which decompose the sponge tissues, leaving the skeleton behind. Bacteria are, after all, often very useful. But in spite of the good they do, their harmfulness is manifest, for they cause diseases, many of which are "catching" or infectious.

**Bacteria cause Disease.** — Certain bacteria cause disease by living as parasites in the human body. Millions upon millions of bacteria exist in the human body at all times — in the mouth, on the teeth, and especially in the lower part of the food tube. Some in the food tube are believed to be useful, others harmless; still others cause decay of the teeth, while a few kinds, if present on the roots of the teeth, may cause disease.



A single cell scraped from the roof of the mouth and highly magnified. The little dots are living bacteria, most of them comparatively harmless.

It is known that bacteria, like all other living things, feed and give off organic wastes. These wastes, called *toxins*, are often poisons to the hosts on which the bacteria live, and it is usually the production of a toxin that causes the symptoms of disease. Some bacteria, however, break down tissues and plug up the small blood vessels, thus causing symptoms of disease.

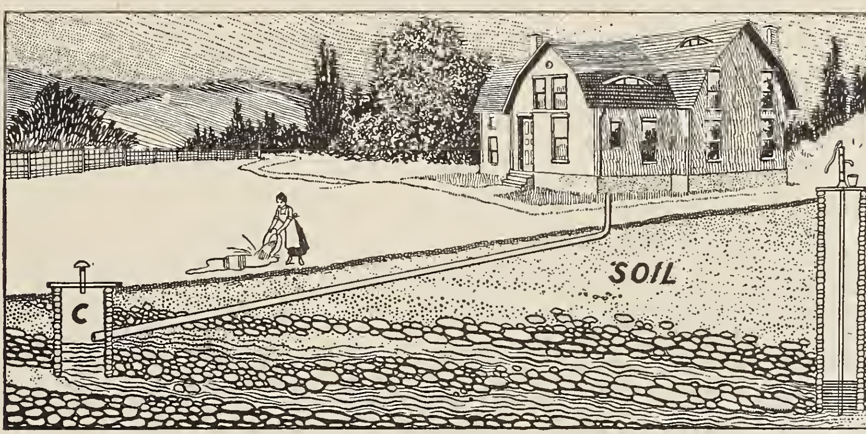
**Diseases caused by Bacteria.** — It is estimated that bacteria cause annually over 50 per cent of the deaths of the human race. As we shall see later, a very large proportion of these diseases might be prevented if people were educated sufficiently to take the proper precautions to prevent their spread. These precautions might save the lives of some 3,000,000 people yearly in Europe and America. Tuberculo′sis, typhoid fever, diphtheria (dĭf-thē′rĭ-a), pneumonia (nū-mō′nĭ-a), blood poisoning, syphilis (sĭf′ĭ-lĭs), and a score of other "germ" diseases ought not to exist. A good deal of the present misery of this world might be prevented and this earth made cleaner and better by the coöperation of the young people now growing up to be our future home-makers.

**How Germs get into the Body.** — Germs of contagious diseases enter the body either by way of the mouth, nose, or other body openings or through a break in the skin. They leave the body of an infected person with the excretions, especially those from the nose, mouth, and intestine. They may be carried by means of air, food, or water, and are usually acquired from the diseased person either by personal contact, by handling articles used by the sick, or by using foods which have been infected. Most germ diseases start with running at the nose, cough or sore throat, slight fever or headache. If children and grown-ups who have these symptoms could be kept away from other people, many an outbreak of contagious disease would be avoided.

**Tuberculosis.** — The one disease responsible for the greatest number of deaths — about one tenth of the total on the globe — is tuberculosis. But this disease is slowly but surely being overcome. It is believed that within perhaps fifty years with the application of the knowledge that every high-school boy and girl now has and with the additional aid of good laws and of sanitary living, it will be almost extinct.

Tuberculosis is caused by the growth of bacteria, called *tubercle bacilli*, within the lungs or other tissues of the human body. In the lungs they form little tubers full of germs, which close up the delicate air passages. In other tissues they may give rise to hip-joint disease, scrofula, lupus, and other diseases, depending on the part of the body attacked. Many believe

that tuberculosis may be contracted by eating meat or drinking milk from tubercular cattle. It is most often communicated from a consumptive (tuberculous) to a well person by kissing, or by using the same cup, plate, towels, or by spraying the germs from the mouth of the consumptive out into the nose or mouth of another person by coughing, sneezing, or even talking close to his face. Although there are always some tuberculosis germs in the air of an ordinary city street, and although we may take some of these germs into our bodies at any time, yet the bacteria seem able to gain a foothold only under certain conditions. It is only when the tissues are in a worn-out condition, when we are "run down," as we say, that the parasite may obtain a foothold in the lungs. Even if the disease gets a foothold,




How sewage containing typhoid bacteria may get into drinking water: *c*, cesspool.

it is quite possible to cure it if it is taken in time. The germ of tuberculosis is killed by exposure to bright sunlight and fresh air. Thus the course of the disease may be arrested, and a permanent cure brought about, by a life in the open air, the patient sleeping out of doors, taking plenty of nourishing food and very little exercise. (See also Chapter XXX.)

**Typhoid Fever.** — One of the most common germ diseases in this country and Europe used to be typhoid fever. This is a disease which is conveyed by flies and by water and food, especially milk, oysters, and uncooked vegetables. Typhoid fever germs live in the intestine, where they multiply very rapidly and are

passed off from the body with the excreta from the food tube. If these germs get into the water supply of a town, an epidemic of typhoid will result. Among the epidemics caused by the use of water containing typhoid germs have been those in Butler, Pa., where 1364 persons were made ill; Ithaca, N.Y., with 1350 cases; and Watertown, N.Y., where over 5000 cases occurred. Fortunately most water supplies of cities are now made safe by filtration and chlorina′tion. (See Chapter XXX.) Another source of infection is milk. Frequently epidemics have occurred which were confined to users of milk from a certain dairy. Upon investigation it was found that a case of typhoid had occurred on the farm where the milk came from, that the germs had washed into the well, and that this water was used to wash the milk cans. Once in the milk, the bacteria multiplied rapidly, so that the milkman gave out cultures of typhoid in his milk bottles. Pasteurization and proper inspection of our milk supply are necessary if we are to prevent epidemics of typhoid under the present conditions. The only sure way to keep from having the disease is to be vaccinated against typhoid. (See Chapter XXX.)

**Tetanus.** — The bacterium causing tet′anus, or blood poisoning, is another toxin-forming germ. It lives in the earth and enters the body through cuts or bruises. It seems to thrive best in less oxygen than is found in the air. It is therefore important not to close up with court-plaster wounds in which such germs may have found lodgment.

**Other Diseases.** — Many other diseases have been traced to bacteria. Diphtheria is one of the best known. As it is a throat disease, it may easily be conveyed from one person to another by kissing, putting into the mouth objects which have come in contact with the mouth of a patient having diphtheria, or by food into which the germs have found their way. Septic sore throat is another disease which is easily spread through milk supplies, as is scarlet fever. The venereal diseases, gonorrhoea and syphilis, probably cause more misery than any other germ diseases. They cause hundreds of thousands of children to be born crippled, blind, or otherwise handicapped for life and are responsible for the deaths of many young mothers. Grippe,

pneumonia, whooping cough, and colds are believed to be caused by bacteria. But other diseases, as malaria, yellow fever, sleeping sickness, and probably smallpox, scarlet fever, and measles, are due to the attack of one-celled animal parasites. Of these we shall learn later in the chapter on Protozoa.

**Methods of fighting Germ Diseases.** — As we have seen, diseases produced by bacteria may be caused by the bacteria being transferred from one person directly to another, or the disease germs may gain an entrance into the body with food, water, or air, or by taking them into the blood through a wound or a body opening.

It is evident that as individuals we may each do something to prevent the spread of germ diseases, particularly in our homes. We may keep our bodies, especially our hands and faces, clean. Green soap and hot water are as good cleansing agents as we can get. Sweeping and dusting may be done with damp cloths so as not to raise a dust; water, when from a suspicious supply, should be *sterilized,* — that is, boiled to kill any germs contained in it, — and milk should be pasteurized.

**Uses of Antiseptics.** — About the year 1867, an Edinburgh surgeon, Lister, decided that germs floating in the air entered wounds and caused blood poisoning among his hospital patients. So he began washing their wounds with weak carbolic acid and covering them with gauze wet with carbolic acid. In a short time he proved to the world the value of *antisep'tics* or materials that prevent bacteria from growing. We have largely given up carbolic acid to-day and use iodine for cuts or bruises. For sore throat argyrol (15 per cent) is best; for inflamed eyes a saturated solution of boracic acid is good; while an excellent mouth wash is salt and warm water (about a half-teaspoonful of salt to a cup of water).

**Summary.** — The knowledge gained from the study of this chapter should be of much practical value to every boy and girl. We have seen that green plants not only have a decided economic value in producing foods, medicines, dyestuffs, clothes, paper, lumber, and fuel, but they also regulate our water supplies, moderate our climate, and use that greatest source of energy, the sun, for man's good.

The plants without chlorophyll may be harmful, or harmless or valuable. Some, like the yeasts, are of definite use in the process of fermentation and bread making; others, the molds, have a slight value but do more harm than good in spoiling food. The third great group, the bacteria, are man's greatest friends as well as his most deadly foes. Without them decay would not take place — try to imagine life on the earth with no way to get rid of dead matter. They also give flavor to cheese and milk, and to other foods; they are useful in the tanner's trade as well as in many other kinds of work where decomposition plays a part. And the fertility of the soil depends upon certain kinds of bacteria, especially those which "fix" free nitrogen from the air.

On the other side of the scale we can pile up a great weight against the bacteria. Probably nearly 75 per cent of all people on the earth die of diseases caused by bacteria and other parasites which could have been prevented. The great mortality among young children is due largely to bacteria causing diarrhea, the tuberculosis germ is responsible for over one tenth of all the deaths on the earth, while pneumonia, influenza, typhoid, venereal diseases, and many others either kill or weaken people so that many die before reaching the threescore years and ten allotted to them. This chapter and the ones which treat of health and our civic obligations (XXIX and XXX) are among the most important in the book for us.

**Problem Questions.** — 1. What are some of the uses of green plants not mentioned in this chapter?

2. Why do the farmers need bacteria? Mention all the ways in which they are useful.

3. In what ways do farmers need to guard against bacteria?

4. In what trades are yeasts useful? Harmful?

5. In what trades are molds useful?

6. Do bacteria do more harm or good? Give reasons for both sides of your argument.

7. What specific diseases have you been able to find caused by bacteria?

8. What methods would you use to prevent "taking" an infectious disease?

**9.** What are the best methods of controlling the growth of bacteria?

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## XIV. THE RELATIONS OF PLANTS TO ANIMALS

***Problem.*** *To discover the general biological relations existing between plants and animals.* (*Laboratory Manual, Prob. XXIV; Laboratory Problems, Probs. 108 to 111.*)

(*a*) *A balanced aquarium.*
(*b*) *Relations between green plants and animals.*
(*c*) *The nitrogen cycle.*
(*d*) *A hay infusion.*

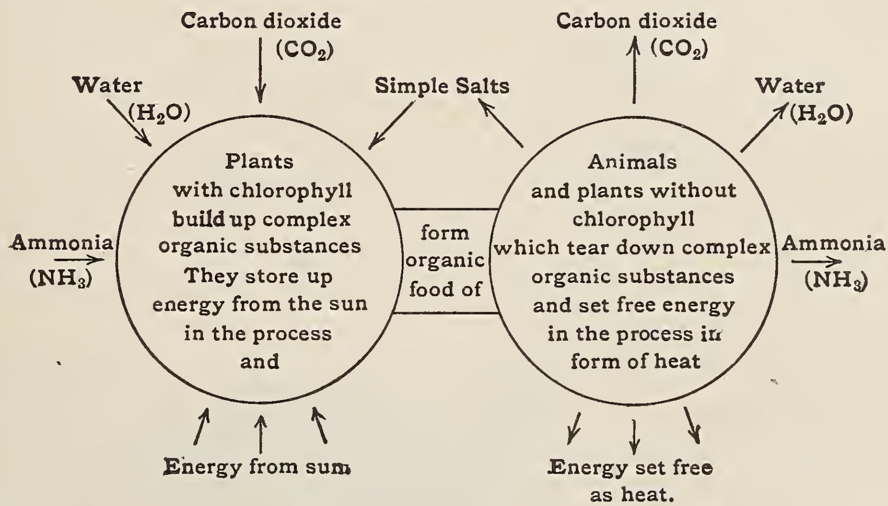
**Study of a Balanced Aquarium.** — Perhaps the best way for us to understand the interrelation between plants and animals is to study an aquarium in which plants and animals live and in which a balance has been established between the plant life on one side and animal life on the other. Aquaria containing green pond weeds, either floating or rooted, a few snails, some tiny animals known as water fleas, and a fish or two will, if kept near a light window, show this relation. (See Frontispiece.)

We have seen that green plants under favorable conditions of sunlight, heat, moisture, and with a supply of raw food materials, give off oxygen as a by-product while manufacturing food in the green cells. We know the necessary raw materials for starch manufacture are carbon dioxide and water, while nitrogenous material is necessary for the making of proteins within the plant. In previous experiments we have proved that carbon dioxide is given off by any living thing when oxidation occurs in the body. The crawling snails and the swimming fish give off carbon dioxide, which is dissolved in the water; the plants themselves, night and day, oxidize food within their bodies, and so must pass off some carbon dioxide. The green plants in the sunlight use up the carbon dioxide obtained from the various sources and, with absorbed water, manufacture starch. While this process is going on, oxygen is given off to the water of the aquarium, and this is used by the animals.

But the plants are continually growing larger. The snails and

fish, too, eat parts of the plants. Thus the plant life gives food to part of the animal life within the aquarium. The animals give off certain nitrogenous wastes which are used in the manufacture of protein within the plant. The animals eat the plants and give off organic waste, which the plants use as food and make into living matter. When the plants give off as much oxygen as the animals use and the animals give off as much carbon dioxide as the plants use, the aquarium is balanced.

**Relations between Green Plants and Animals.** — What goes on in the aquarium is an example of the relation existing between

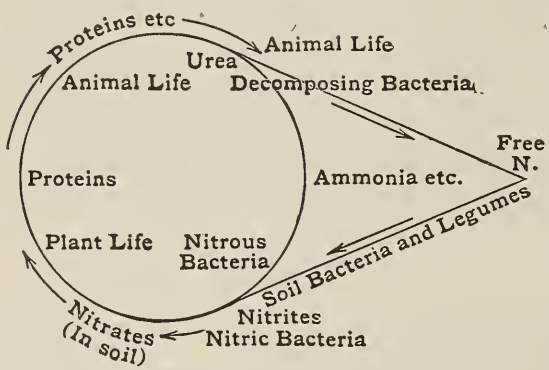



The relations between green plants and animals.

all green plants and all animals. Everywhere in the world green plants are making food which becomes, sooner or later, the food of animals. Man may not feed upon the leaves of plants, but he eats fruits and seeds in one form or another. Even if he does not feed directly upon plants, he eats the flesh of herbivorous animals, which in turn feed directly upon plants. And so it is the world over; the plants are the food-makers and supply the animals. Green plants also give a very considerable amount of oxygen to the atmosphere every day, which the animals may make use of.

**The Nitrogen Cycle.** — The animals in their turn supply much of the carbon dioxide that the plant uses in starch-making. They also supply most of the nitrogenous matter used

by the plants, whether from the decay of dead bodies or the excretions of the living. Bacteria which live upon the roots of certain plants, are the only organisms that can take nitrogen from the air. Thus, in spite of all the nitrogen of the atmosphere, plants and animals are limited in the amount available. And the available supply is used over and over again, perhaps in nitrogenous food by an animal, then it may be given off as organic waste, get into the soil, and be taken up by a plant through the roots. Eventually the nitrogen forms part of the food supply in the body of the plant, and then may become part of its living matter. When the plant dies, the nitrogen is returned to the soil. Thus the usable nitrogen is kept in circulation.



The nitrogen cycle.

**Symbiosis.**—Plants and animals are seen in a general way to be of mutual advantage to each other. Some plants, called *lichens,* show this mutual partnership in the following interesting way. A lichen is composed of two kinds of plants, one of which at least may live alone, but the two plants have formed a partnership for life, and have divided the duties of such life between them. In most lichens the alga, a green plant, forms starch and nourishes the fungus. The fungus, in turn, produces spores, by means of which


A lichen (*Physcia stellaris*). Photographed by W. C. Barbour.

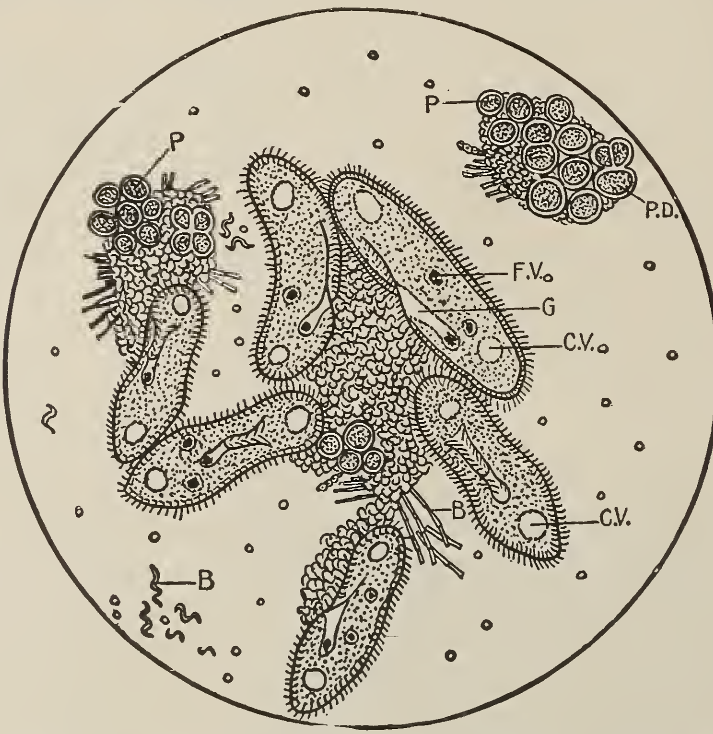
new lichens are started in life; moreover, the lichen is usually protected by the fungus, which is stronger in structure than the green part of the combination. *This process of living together for mutual advantage is called symbio'sis.* Some animals also combine with plants; for example, the tiny animal known as the hydra with certain of the one-celled algæ, and, if we accept the term in a wide sense, all green plants and animals live in this relation of mutual give and take. Animals also frequently live in this relation to each other, as the tiny crab which lives within the shell of the oyster; and the sea anemones which are carried around on the backs of some hermit crabs, aiding the crab in protecting it from its enemies, and being carried about by the crab to places where food is plentiful.

Stages in the formation of the lichen thallus, showing the relation of the threadlike fungus to the green cells of the alga. (After Bornet.)

**A Hay Infusion.** — Still another example of the close relation between plants and animals may be seen in the study of a hay infusion. If we place a wisp of hay or straw in a small glass jar nearly full of water, and leave it for a few days in a warm room, certain changes are seen to take place in the contents of the jar; the water after a little while gets cloudy and darker in color, and a scum appears on the surface. If some of this scum is examined under the compound microscope, it will be found to consist almost entirely of bacteria. These bacteria evidently aid in the decay which (as the unpleasant odor from the jar testifies) is taking place. As we have learned, bacteria flourish wherever the food supply is abundant. The water within the jar has come to contain much of the food material which was once within the leaves of the grass, — organic nutrients, starch, sugar, and proteins, formed in the leaf by the action of the sun on the chlorophyll of the leaf, and now released into the water by the breaking down of the walls of the cells. The bacteria themselves release this food from the hay by causing it to decay. After a few days small one-celled animals appear which multiply with wonderful rapidity. Hay is dried grass, upon which the wind may have scattered some of these

little organisms in the dust from a dried-up pool. Existing in a dormant state on the hay, they are awakened by the water to active life. In the water, too, there may have been some living cells, plant and animal.

At first the multiplication of the tiny animals within the hay infusion is extremely rapid; there is food in abundance and near at hand. After a few days more, however, several kinds of




Life in a late stage of a hay infusion. *B*, bacteria, swimming or forming masses of food upon which the one-celled animals, the paramecia, are feeding; *G*, gullet; *F.V.*, food vacuole; *C.V.*, contractile vacuole; *P*, pleurococcus; *P.D.*, pleurococcus dividing. Highly magnified.

one-celled animals may appear, some of which prey upon others. Consequently a struggle for life begins, which becomes more and more intense as the food from the hay is used up. Eventually the end comes for all the animals unless some green plants obtain a foothold within the jar. If such a thing happens, food will be manufactured within their bodies, a new food supply arises for the animals within the jar, and a balance of life results.

**Summary.** — This chapter shows us that there exists a give and take relationship between green plants and animals which is illustrated by the condition known as *symbiosis*.

**Problem question.** — 1. How does the balanced aquarium illustrate symbiosis?

2. Explain the nitrogen cycle, the carbon cycle, the oxygen cycle.

3. What kind of a relationship does life within a hay infusion represent?

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## XV. THE PROTOZOA

***Problem.*** *The study of a one-celled animal.* (*Laboratory Manual, Problem XXV; Laboratory Problems, Probs. 112, 113.*)

(*a*) *In its relation to its surroundings.*

(*b*) *As a cell.* (*Optional.*)

(*c*) *In its relations to man.*

**A Simple Plant Cell.** — We have seen that perhaps the simplest plant would be exemplified by one of the tiny bacteria we have just read about. A typical one-celled plant, however, would contain green coloring matter or chlorophyll, and would have the power to manufacture its own food under conditions giving it a moderate temperature, a supply of water, oxygen, carbon dioxide, and sunlight. Such a simple plant is the pleurococcus, the " green slime " seen on the shady side of trees, stones, or city houses. This plant would meet our definition of a cell, as it is a minute mass of protoplasm inclosed in a cell membrane and containing a nucleus. It is surrounded by a wall[1] of a woody material which covers the delicate membrane formed by the activity of the protoplasm within the cell. It also contains green granules called chloroplasts. Of their part in the manufacture of organic food we have already learned. Such is a simple plant cell. Let us now examine a simple animal cell in order to compare it with that of a plant.

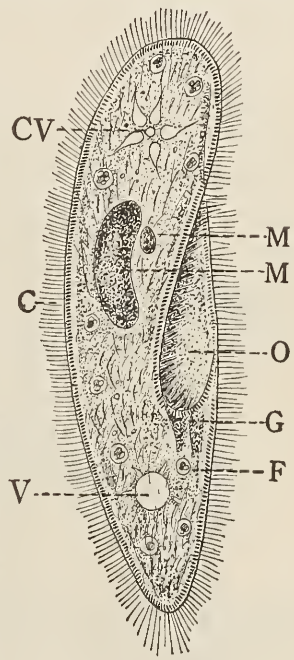
**The Paramecium.** — The one-celled animal most frequently found in hay infusions is the *paramecium* (păr-a-mē′shĭ-um), or slipper animalcule (so-called because of its shape).

This cell is elongated, oval, or elliptical in outline, but somewhat flattened. Seen under the low power of the microscope, it appears to be extremely active, rushing about now rapidly, now more slowly, but seemingly always taking a definite course.

[1] This shows one practical reason why plant food often contains more indigestible matter than animal food of same bulk.

The rounded end of the body (the *anterior* end) usually goes first. If it pushes its way between dense substances in the water, the cell body is seen to change its shape as it squeezes through.

The cell body is almost transparent, and consists of semifluid protoplasm which has a granular, grayish appearance under the microscope. This protoplasm appears to be bounded by a very delicate membrane (the cu′ticle) through which project numerous delicate threads of protoplasm called *cilia* (sĭl′ĭ-a). (These are seen with difficulty under the microscope.)



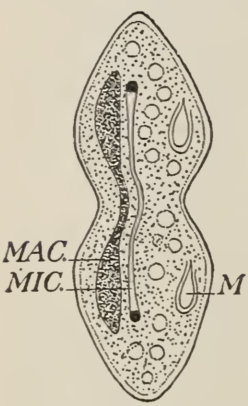
Paramecium: *C*, cilia; *CV*, contractile vacuole; *F*, food vacuole; *O*, mouth; *G*, gullet; *M*, macronucleus; *Mi*, micronucleus; *V*, vacuole.

The locomotion of the paramecium is caused by the movement of these cilia, which lash the water like a multitude of tiny oars. The current of water caused by the cilia carries tiny particles of food into a funnel-like opening, the *gullet,* on one side of the cell. Once within the cell body, the particles of food materials are gathered into little balls within the almost transparent protoplasm. Each mass of food seems to be inclosed within a little area containing fluid, called a *vacuole* (văk′ū-ōl). Other vacuoles appear to be clear; these are spaces in which food has been digested. One or two larger vacuoles may be found; these are the *contractile vacuoles;* their purpose seems to be to pass off waste material from the cell body. This is done by the pulsation of the vacuole, which ultimately bursts, passing fluid waste to the outside. Solid wastes are passed out of the cell in somewhat the same manner. The nucleus of the cell is not easily visible in living specimens. In a cell that has been stained it has been found to be a double structure, consisting of one large and one small portion, called respectively the *macronucleus* and the *micronucleus.*

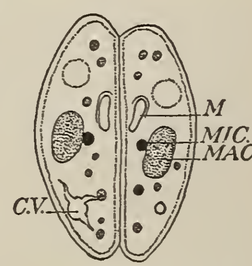
**Response to Stimuli.** — In the paramecium, as in the one-celled plants, the protoplasm composing the cell can do certain

things. Protoplasm responds, in both plants and animals, to certain agencies acting upon it, coming from without; these agencies we call *stimuli*. Such stimuli may be light, differences of temperature, presence of food, electricity, or other factors in its surroundings. Plant and animal cells may react differently to the same stimuli. In general, however, we know that protoplasm is *irritable* to some of these factors. To severe stimuli, protoplasm usually responds by *contracting*, another power which it possesses. We know, too, that plant and animal cells take in food and change the food to protoplasm, that is, that they *assimilate* food; and that they may waste away and repair themselves. Finally, we know that new plant and animal cells are *reproduced* from the original bit of protoplasm, a single cell.

**Reproduction of Paramecium.** — Sometimes a paramecium may be found in the act of dividing by the process known as *fission*, to form two new cells, each of which contains half of the original cell. In this process the nucleus first elongates and breaks into two, and the halves go to opposite ends of the cell. The cell elongates, a second gullet appears, and ultimately the cell breaks into two parts, each half provided with a nucleus and a gullet (see diagram). This is a method of *asexual* reproduction.




Paramecium dividing by fission. Highly magnified. *M*, mouth; *MAC.*, macronucleus; *MIC.*, micronucleus. (After Sedgwick and Wilson.)

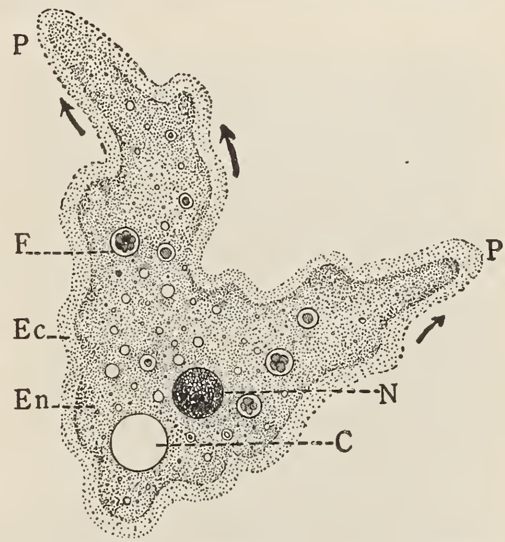



Paramecium, highly magnified; two cells just before conjugation. *M*, mouth; *MIC.*, micronucleus; *MAC.*, macronucleus; *C.V.*, contractile vacuole. (After Sedgwick and Wilson.)

Frequently another stage of reproduction may be observed. This is called *conjugation*, and somewhat resembles conjugation in the simple plants. Two cells of equal size attach themselves together as shown in the Figure. Complicated changes take place in the nuclei of the two cells thus united, which results in an exchange of parts of the material forming the nuclei of each cell. After a short period of rest the two cells separate. The stage of conjugation we

believe in the plants to be a *sexual* stage. There seems every reason to believe that it is a like stage in the life history of the paramecium.

**Amœba.**[1] — In order to understand more fully the life of a simple bit of protoplasm, let us take up the study of the *amœ'ba*, a type of the simplest form of life known, either plant or animal. Unlike the plant and animal cells we have examined, the amœba has no fixed form. Viewed under the compound microscope, it has the appearance of an irregular mass of granular protoplasm. Its form is constantly changing as it moves about. This is due to the pushing out of tiny projections of the protoplasm of the cell, called *pseudopodia* (sū-do-pō'dĭ-a; false feet). The outer layer of protoplasm is not so granular as the inner part; this outer layer is called *ec'toplasm*, the inside being called *en'doplasm*. In the central part of the cell is the nucleus. Several theories have been advanced to account for locomotion. The most likely one seems to be that the pseudopodia are elastic and when stretched out fasten themselves. The rest of the body then flows into the extended end. Some writers think the amœba progresses by a kind of rolling motion. The pseudopodia are pushed out in the direction in which the animal is to go, the rest of the body following.

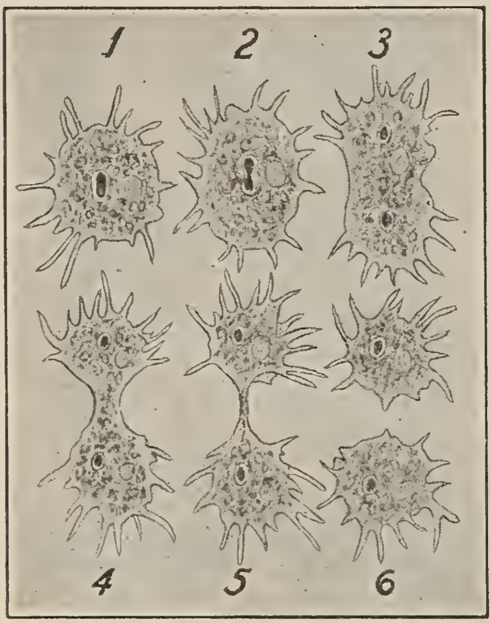



An amœba in search of food. *P*, pseudopodium; *F*, food vacuole; *Ec*, ectoplasm; *En*, endoplasm; *C*, contractile vacuole; *N*, nucleus.

Although but a single cell, still the amœba appears to be aware of the existence of food when it is near at hand. Food may be taken into the body at any point, the semifluid protoplasm

[1] Amœbæ *may* be obtained from the hay infusion, from the dead leaves in the bottom of small pools, from the same source in fresh-water aquaria, from the roots of duckweed or other small water plants, or from green algæ growing in quiet localities. No *sure* method of obtaining them can be given.

simply rolling over and engulfing the food material. Within the body, as in the paramecium, the food is inclosed within a fluid space or vacuole. The protoplasm has the power to take out such material as it can use to form new protoplasm or to give energy. It will then rid itself of any material that it cannot use. Thus it has the power of *selective absorption,* a property found in the protoplasm of plants previously studied. Circulation of food material is accomplished by the constant streaming of the protoplasm within the cell. The cell absorbs oxygen from the air in the water by osmosis through its delicate membrane, giving out carbon dioxide in return. Thus respiration takes place through every part of the covering of the cell. Waste products other than carbon dioxide formed from the life activities which take place within the cell are passed out by means of the contractile vacuole.



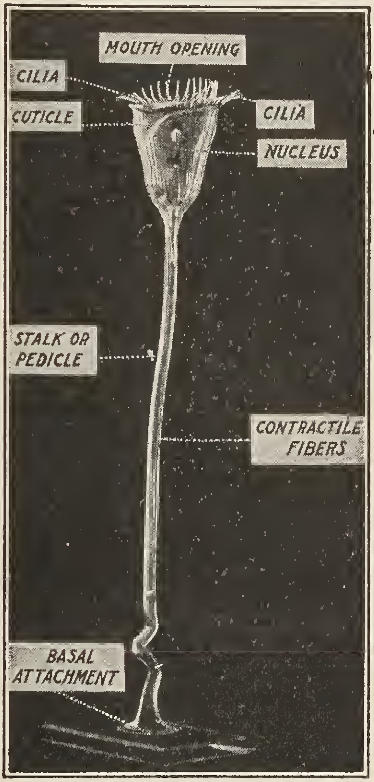

Amœba, highly magnified, showing the changes which take place during division. The dark body in each Figure is the nucleus; the transparent circle, the contractile vacuole; the outer, clear portion of the body, the ectoplasm; the granular portion, the endoplasm; the granular masses, food vacuoles.

The amœba, like other one-celled organisms, reproduces by the process of fission. A single cell divides by splitting into two, each of which resembles the parent cell, except that it is of smaller size. When these new cells become the size of the parent amœba, they each divide. This is a kind of asexual reproduction. When conditions unfavorable for life come, the amœba, like some one-celled plants, encysts itself within a membranous wall. In this condition it becomes dried and is blown through the air. Upon return to a favorable environment, the cover disappears and life begins again, as before. In this respect the amœba resembles the spore of a plant.

From the study of the amœbalike organisms which are known to cause malaria, and by comparison with the amœbæ which live in ponds and swamps, it seems likely that every amœba has a complicated life history during which it passes through a *sexual* stage of existence.

**The Cell as a Unit.** — In the daily life of a one-celled animal we find the single cell performing all the vital activities which we shall later find that the many-celled animal is able to perform. In the amœba no definite parts of the cell appear to be set off to perform certain functions; but any part of the cell can take in food, can absorb oxygen, can change the food into protoplasm and excrete the waste material. The single cell is, in fact, an organism able to carry on the business of living as effectually as a very complex animal.

**Complex One-celled Animals.** — In the paramecium we find a single cell but certain parts of the cell have certain definite functions: the cilia are used for locomotion; a definite part of the cell takes in food, while another definite spot passes out the waste. In another one-celled animal called *vorti-cel'la,* part of the cell has become very much elongated and is contractile, forming a stalk by which the little animal is fastened to a water plant or other object. The stalk may be said to act like a muscle fiber, as its sole function seems to be movement; the cilia are located at one end of the cell and serve to create a current of water which brings food particles to the mouth. Here we have several parts of the cell each doing a different kind of work. This is known as *physiological division of labor.*

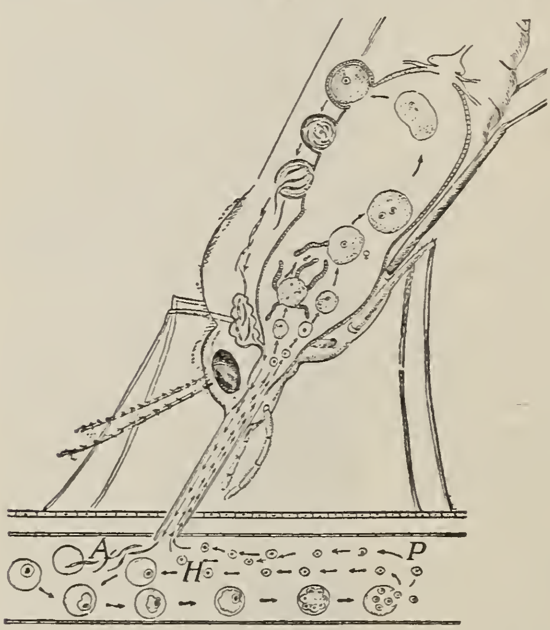


Vorticella, highly magnified. Photograph from American Museum of Natural History.

**Habitat of Protozoa.** — *Protozo'a,* or one-celled animals, are found in shallow water almost everywhere, seemingly never at any great depth. They appear to be attracted to the surface by light and the supply of oxygen. Every fresh-water lake swarms with them; the ocean contains countless myriads of many different forms.

**Use as Food.** — Protozoa are so numerous in lakes, rivers, and the ocean as to form the food for many animals higher in the scale of life. Almost all fish that do not take the hook and that travel in schools, or companies, migrating from one place to another, live partly on such food. Many feed on slightly larger animals, which in turn eat the Protozoa. Such fish have on each side of the mouth attached to the gills a series of small structures looking like tiny rakes. These are called the gill rakers, and aid in collecting tiny organisms from the water as it passes over the gills.

**Relation of Protozoa to Disease.** — The study of the life history and habits of the Protozoa has resulted in the finding of many parasitic forms, and the consequent explanation of some kinds of disease. One parasitic protozoan like the amœba causes the disease known as malaria. Part of its life is passed within the body of a mosquito,— the *anopheles* (a-nŏf′ĕ-lēz), — into the stomach of which it passes when the mosquito sucks blood from a person having malaria. Within the body of the mosquito a complicated part of the life history takes place, which results in a stage of the parasite establishing itself within the glands which secrete the saliva of the mosquito. When the mosquito pierces its human prey the next time, some of the parasites are introduced with the saliva into the victim's blood. These parasites enter the red corpuscles




Life history of the malarial parasite. The mosquito injects crescent-shaped bodies *A* into the blood of man. Spores develop in the blood corpuscles, and many, as at *H*, may enter other corpuscles, while some (*P*) may be drawn into the body of a mosquito, where the parasite passes through sexual stages. Follow the course shown by the arrows from *A* back to *A*, and from *H* back to *H*.

of the blood, increase in size, and then form spores. The rapid process of spore formation results in the bursting of the blood corpuscles, and the parasites enter the fluid portion of the blood. The chill and fever are probably caused by the destruction of the corpuscles and release of poison into the blood. The parasites again enter the blood corpuscles and in forty-eight or seventy-two hours repeat the process thus described. Yellow fever is undoubtedly conveyed by another species of mosquito, and is due to the presence of a protozoan similar to that of malaria in the blood. That these diseases may be stamped out by the extermination of the mosquitoes, which may be accomplished by the use of oil to prevent their breeding in swamps, by draining the swamps, or by the introduction of fish which eat the mosquito larvæ, has been proved from our experience along the Panama Canal, in the Philippines, in Cuba, and in New Orleans.

Many other diseases of man are probably caused by parasitic protozoans. Dysentery appears to be caused by the presence of an amœbalike animal in the digestive tract. Smallpox, rabies, and possibly other diseases may be caused by the action of these little animals.

Another group of protozoan parasites are called *trypanosomes* (trĭp′a-no-sōmz). One of this family lives in the blood of native African zebras and antelopes; seemingly it does them no harm. But if one of these parasites is transferred by the dreaded tsetse (tsĕt′sĕ) fly to one of the domesticated horses or cattle of the colonists in Central or Southern Africa, death of the animal results.

Another fly carries a specimen of trypanosome to the natives of Central Africa, which causes "the dreaded and incurable sleeping sickness." This disease has carried off more than fifty thousand natives in a year, and many Europeans have succumbed to it. Its ravages are now largely confined to an area near the large Central African lakes and the upper Nile, for the fly which carries the disease lives near water, seldom going more than 150 feet from the banks of streams or lakes. The British government is now trying to control the disease in Uganda by moving all the villages at least two miles from the lakes and rivers. Why? In this country many fatal diseases

of cattle, as "tick," or Texas fever, are probably caused by protozoans.

**Skeleton Building.** — Some of the Protozoa build elaborate skeletons. These may be formed either in or outside of the body, and are often of great beauty when seen under the microscope (see Figure). Much of the chalk in various parts of the world is made of the skeletons of these tiny creatures.

Skeleton of a radiolarian. Highly magnified. From model at American Museum of Natural History.

### A Simple Classification of Protozoa

The following are the principal classes of Protozoa, examples of which we have seen or read about: —

Class I. *Rhizop'oda* (Greek — root-footed). Having no fixed form; with pseudopodia. Either naked as *Amœba* or building limy (*Foraminif'era*) or glasslike skeletons (*Radiola'ria*).

Class II. *Infusor'ia* (infusions). Usually active ciliated Protozoa. Examples, *Paramecium, Vorticella.*

Class III. *Sporozo'a* (spore animals). Usually parasitic and nonactive. Example, the parasite that causes malaria (*Plasmodium malariæ*).

**Summary.** — This study has shown us that a single-celled animal has all the vital functions of a more complex one. It feeds, digests, and assimilates its food, breathes, excretes waste, and reproduces. It is sensitive to outside stimuli and responds by movement. It is in other words a living organism.

**Problem Questions.** — 1. Describe the life cycle of a paramecium.

2. Compare two stages of reproduction in paramecium.

3. What relation do the Protozoa bear to malaria? Explain.

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## XVI. SIMPLE METAZOA — DIVISION OF LABOR

***Problem.*** *An introductory study of many-celled animals to learn something about —*

(*a*) *Their development.*
(*b*) *The structure of a sponge.*
(*c*) *The hydra.*
(*d*) *The development of tissues and organs.*
(*e*) *The common functions of all animals.*

(*Laboratory Manual, Prob. XXVI; Laboratory Problems, Probs. 116, 117.*)

**Reproduction in Plants.** — Although there are very many plants and animals so small and so simple as to be composed of but a single cell, by far the greater part of the animal and plant world is made up of individuals which are collections of cells living together.

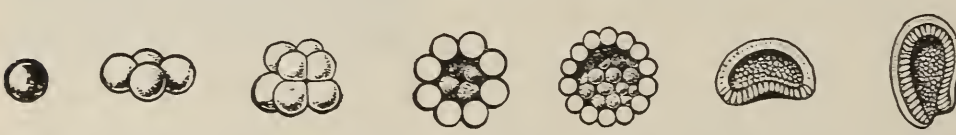
In a simple plant like the pond scum, a string or filament of cells is formed by a single cell dividing crosswise, each of the two cells thus formed giving rise to two more, and so on, until eventually a long thread of cells results. Such growth of cells is asexual.

In some instances, however, a single cell is formed by the union of two cells, one from each of the adjoining filaments of the plant. Around this cell eventually a hard coat is formed, and the *spore*, as it is called, is thus protected from unfavorable changes in the surroundings. Later, when conditions become favorable for its germination, the spore may form a new filament of pond scum.

In the seed plants, too, we found within the seed a little plant, an embryo, which, under favorable conditions, may give rise, through the rapid multiplication of the cells forming it, to a new plant. The embryo first arises from two cells, one of which, called a sperm, comes from a pollen grain, while the other, the egg, is found within the embryo sac of the ovary.

**Reproduction in Animals.** — Similarly, in the reproduction of many-celled animals the new individual is formed by the union of a sperm and an egg cell. A common bath sponge, an earthworm, a fish, and a dog, — each and all of them begin life in precisely the same way. Animals which are thus composed of many cells are known as the *Metazo'a*, as distinguished from the *Protozoa*, which are made of but a single cell.

**Sexual Development of a Simple Animal.** — In a many-celled animal the life history begins with a single cell, the fertilized egg. This cell, as we remember, has been formed by the union of two other cells, a tiny (usually motile) cell, the *sperm*, and a large cell, the *egg*. After the egg is fertilized by a sperm cell, it splits into two, then into four, then into eight, then into sixteen cells, and so on; as the number of cells increases, a hollow ball of cells called the *blas'tula* is formed; later this ball

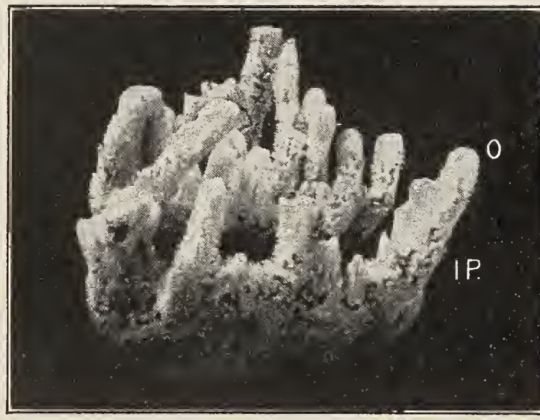


Stages in the segmentation of an egg, showing the formation of the gastrula.

sinks in on one side, and a double-walled cup of cells, called a *gas'trula*, results. Practically all animals pass through the above stages in their development from the egg, although these stages are often not easy to see because of the presence of food material (yolk) in the egg. In the development of the sponge the gastrula, which swims by means of cilia, soon settles down, a skeleton is formed, other changes take place, and the sponge begins life as an animal attached to some support in the water. The early stages of life, when an animal is unlike the adult, are known as *larval* stages; the animal at this time being called a larva.

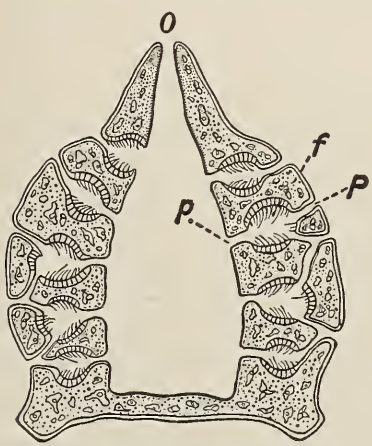
The young sponge consists of three layers of cells: those of the outside, developed from the outer layer of the gastrula, are called *ec'toderm;* the inner layer, developed from the inner layer of the gastrula, the *en'doderm;* and the middle, almost structureless layer, the *mes'oderm.* In higher animals the mesoderm gives rise to muscles and parts of other internal structures.

**The Structure of a Sponge.** — The simplest kind of sponge has the form of an urn, attached at the lower end. A common sponge living in Long Island Sound is a tiny urn-shaped animal less than an inch in length. It has a skeleton made up of very tiny spicules of lime, of different shapes. Cut lengthwise, such an animal is seen to be hollow, its body wall pierced with many tiny pores or holes. The bath sponge, the skeleton of which is made up of fibers of horn, or a variety known as the finger sponge, shows the pores even better than the smaller limy sponge. In a bath sponge, however, we probably have a colony of sponges living together.




A horny fiber sponge; *I P*, the incurrent pores; *O*, osculum. Notice that this sponge is made up of apparently several individuals. One fourth natural size.

Each sponge has a large number of pores opening into a central cavity, which in turn opens by a large hole, called the *os′culum,* to the surrounding water.

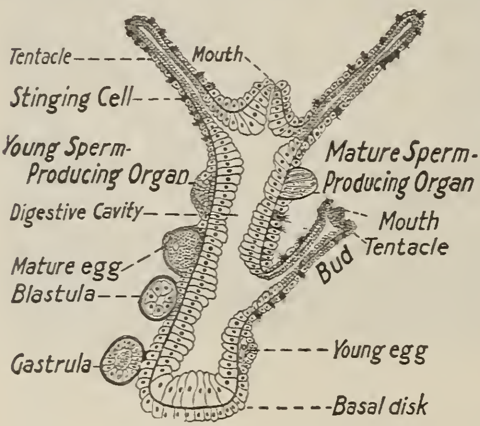



Longitudinal section of a simple sponge: *O*, osculum, *P, P*, incurrent pore; *f*, flagella.

A microscopic examination shows the pores of the sponge to be lined on the inside with cells each having a collar of living matter surrounding a single long cilium called a *flagellum* (fla-jĕl′um). The flagella, lashing in one direction, set up a current of water toward the large inner cavity. This current bears food particles, tiny plants and animals, which are seized and digested by the collared cells, these cells probably passing the food on to the other cells of the body. The jelly-like middle layer of the body is composed of cells which secrete

lime to form the spicules and the reproductive cells, eggs, and sperms.

**The Hydra.** — Another very simple animal, which unlike most sponges lives in fresh water,[1] is called the hydra. This little creature is shaped like a hollow cylinder with a circle of arms or *ten'tacles* at the free end. It is found attached to dead leaves, sticks, stones, or water weeds in most fresh-water ponds. When disturbed, the hydra contracts into a tiny whitish ball a little larger than the head of a pin. Expanded, it may stretch its tentacles in search of food almost an inch from their point of attachment. The tentacles are provided with batteries of minute darts of stinging cells, by means of which prey is caught and killed. The outer layer of the animal serves for protection as well as movement and sensation, certain cells being fitted for each of those different purposes.



Longitudinal section of a hydra, magnified.

**Food Taking.** — The tentacles then reach out like arms, grasp the food, bend over with it, and pull it toward the mouth. Certain cells lining the hollow digestive cavity pour out a fluid which digests the food. Other cells with long cilia circulate the food, while still other cells lining the cavity put out pseudopodia, which grasp and ingest the food particles. The tentacles are hollow, and the digestive cavity extends into them. The outer layer of the animal does not digest the food, but receives some of it already digested from the inner layer. This food passes from cell to cell, as in plants, by osmosis. The oxygen necessary to oxidize the food is passed through the body wall, seemingly at any point, for there are no special organs for respiration.

**Reproduction.** — The hydra reproduces itself either by budding asexually or by means of eggs and sperms, sexually. The bud ap-

[1] A few sponges, for example, *spongilla*, live in fresh water.

pears on the body as a little knob, sometimes more than one coming out on the hydra at the same time. At first the bud is part of the parent animal, the body cavity extending into it. After a short time (usually a few days) the young hydra separates from the old one and begins life alone. This is asexual reproduction.

The hydra also reproduces by eggs and sperms. These sperms are collected in little groups which usually appear near the free end of the animal, the egg cells developing near the base of the same hydra. Both eggs and sperms grow from the outer layer of the animal. The sperms, when ripe, are set free in the water; one of them unites with an egg, which is usually still attached to the body of the hydra, and development begins which results in the growth of a new hydra in a new locality.

The stages passed through in development resemble closely those described on page 182, and it would not be hard to imagine the gastrula stage, turned upside down with a circle of tentacles at the open end. Our gastrula would then be a hydra.

**Division of Labor.** — If we compare the amœba and the paramecium, we find the latter a more complex organism than the former. An amœba may take in food through any part of the body; the paramecium has a definite gullet. The amœba may use any part of the body for locomotion; the paramecium has definite parts of the cell, the cilia, fitted for this work. Since the structure of the paramecium is more complex, we say that it is a "higher" animal. In the vorticella, a still more complex organism, part of the cell has grown out like a stalk, has become contractile, and acts and looks like muscle.

As we look higher in the scale of life, we invariably find that certain parts of a plant or an animal are set apart to do certain work, and only that work. Just as in a community of people, there are some men who do rough manual work, others who are skilled workmen, some who are shopkeepers, and still others who are professional men, so among plants and animals, whereever *collections* of cells live together to form an organism, there is division of labor, some cells being fitted to do one kind of work, while others are fitted to do work of another sort.

As we have seen in plants, this results in a large number of

collections of cells in the body, the cells in each collection being alike in structure and in performing the same function. Such a collection of cells we call a *tissue*. (See Chapter III.)

Frequently several tissues have certain functions to perform in conjunction with one another. The arm of the human body performs movement. To do this, several tissues, as muscles, nerves, and bones, must act together. A collection of tissues which work together to perform one function is called an *organ*.

In the sponge, division of labor occurs between the cells of a simple animal, some cells lining the incurrent pores creating a current of water, and feeding upon the minute organisms which come within reach, other cells building the skeleton of the sponge, still others producing eggs or sperms. Division of labor of a more complicated sort is seen in the hydra. Here the cells which do the same kind of work are collected into tissues, each tissue being a collection of cells, all of which are more or less alike and do the same kind of work. But in higher animals which are more complicated in structure and in which the tissues are found working together to form organs, division of labor is still more developed. In the human arm, an organ fitted for certain movements, think of the number of tissues and the complicated actions which are possible. The most extreme division of labor is seen in the organism which has the most complex actions to perform and whose organs are fitted for such work.

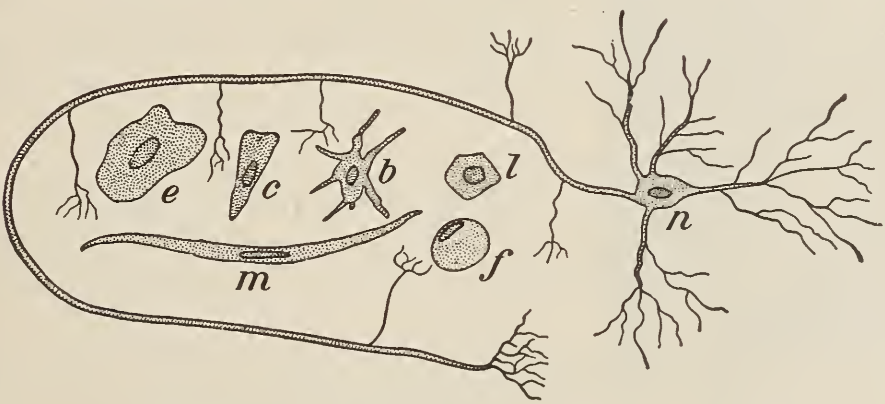
In our daily life in a town or city we see division of labor between individuals. Such division of labor may occur among other animals, as, for example, bees or ants. But it is seen at its highest in a great city or in a large business or industry. In the stockyards of Chicago, division of labor has resulted in certain men performing but a single movement during their entire day's work, but this movement repeated so many times in a day has resulted in wonderful accuracy and increased speed. Thus division of labor attains its end.

**Tissues in the Human Body.** — Every animal body above the protozoan is composed of a certain number of tissues. The cells making up these tissues have certain well-defined characteristics. In very simple animals the cells are all very much alike

but in more complex animals the cells are more and more unlike as their work becomes more and more different. Let us see what these cells may be, what their structure is, and, in a general way, what function each has in the human body.

*Muscle Cells.* — A large part of our body is made up of muscle. Muscle cells are elongated in shape, and have great contractile power. Their work is that of causing movement, and this is usually done by means of attachment to a skeleton inside the body. In man they may be of two kinds, *voluntary* (under control of the will) and *involuntary.*

*Epithelial Cells* cover the outside of a body or line the inside of the cavities in the body. The shape of these cells varies




Diagrams of sections of cells, greatly magnified. *e*, flat cell (epithelium) from mouth; *c*, columnar epithelium from food tube; *b*, bone-forming cell; *l*, liver cell; *m*, muscle cell; *f*, fat cell; *n*, nerve cell.

from flat plates to little cubes or columns depending upon their position in the body. Some bear cilia, an adaptation. Can you think of their purpose?

*Connective Tissue Cells* form the framework between tissues in the body. They are characterized by possessing numerous long processes. Around them is found to a greater or less degree a structureless material, called *intercellular* substance. This stands in the same relation to the cells as does mortar to the bricks in a wall.

Several other types of cells might be mentioned, as *blood cells, cartilage cells, bone cells,* and *nerve cells.* A glance at the Figure shows their great variety of shapes and sizes.

**Functions Common to All Animals.** — The same general functions performed by a single cell are performed by a many-celled animal. But in the Metazoa the various functions of the single cell are taken up by the organs. In a complex organism, like man, the organs and the functions they perform may be briefly given as follows: —

(1) The organs of *food taking.* Food may be taken in by individual cells, as those lining the pores of the sponge, or definite parts of a food tube may be set apart for this purpose, as the mouth and parts which place food in the mouth.

(2) The organs of *digestion:* the food tube and collections of cells which form the glands connected with it. The enzymes in the fluids secreted by the latter change the foods from a solid form (usually insoluble) to that of a *liquid.* Such liquid may then pass by osmosis through the walls of the food tube into the blood.

(3) The organs of *circulation:* the tubes through which the blood, bearing its foods and oxygen, reaches the tissues of the body. In simple forms of Metazoa, as the sponge and hydra, no such organs are needed, the fluid food passing from cell to cell by osmosis.

(4) The organs of *respiration:* the organs in which the blood receives oxygen and gives up carbon dioxide. The outer layer of the body serves this purpose in very simple animals; gills or lungs are developed in more complex animals.

(5) The organs of *excretion:* such as the kidneys and skin, which pass off nitrogenous and other waste matters from the body.

(6) The organs of *locomotion:* muscles and their attachments and connections; namely, tendons, ligaments, and bones.

(7) The organs of *nervous control:* the central nervous system, which has control of coördinated movement. This consists of scattered cells in low forms of life; such cells are collected into groups and connected with each other in higher animals.

(8) The *sense organs:* collections of cells having to do with sight, hearing, smell, taste, and touch.

(9) The organs of *reproduction:* the sperm and egg forming glands.

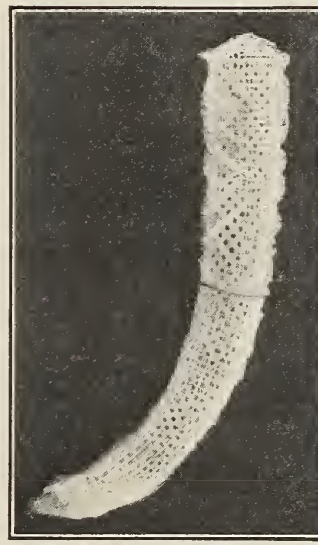
Almost all animals have the functions mentioned above. In most, the various organs mentioned are more or less developed, although in the simpler forms of animal life some of the organs mentioned above are either very poorly developed or entirely lacking.

### Forms of Simple Metazoans. Sponges[1]

Sponges (*Porif'era*) may be placed, according to the kind of skeleton they possess, in the following groups: —

(1) The limy sponges, in which the skeleton is composed of spicules of carbonate of lime. Grantia is an example.

(2) The glassy sponges. Here the skeleton is made of silica or glass. Some of the rarest and most beautiful of all sponges belong in this class. The Venus's flower basket is an example.



Venus's flower basket; a sponge with a glassy skeleton.

(3) The horny fiber sponges. These, the sponges of commerce, have the skeleton composed of tough fibers of material somewhat like that of cow's horn. This fiber is elastic and has the power to absorb water. In a living state, the horny fiber sponge is a dark-colored fleshy mass, usually found attached to rocks. The warm waters of the Mediterranean Sea and the West Indies furnish most of our sponges. The sponges are pulled up from their resting places on the bottom, by means of long-handled rakes operated by men in boats, or they are secured by divers. They are then spread out on the shore in the sun, where bacteria cause the tissues to decay; then after treatment consisting of beating, bleaching, and trimming, the bath sponge is ready for the market.

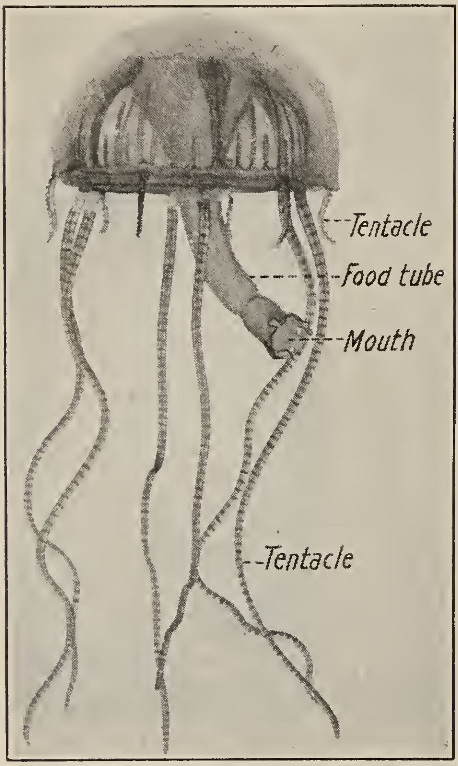
### Cœlenterates

The hydra and its salt-water allies, the jellyfish, hydroids, and corals, belong to a group of animals known as the *Cœlentera'ta*. The word "cœlenterate" (*cœlom* = body cavity, *enteron* = food tube) explains the struc-

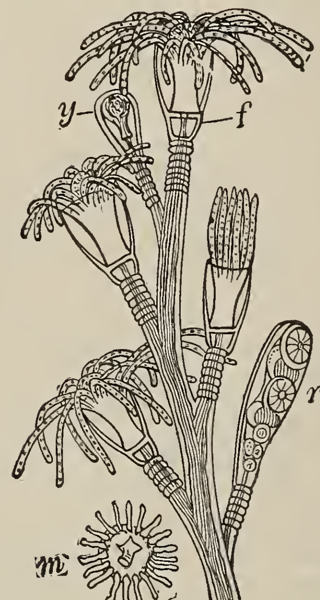
[1] The matter in small type in this and other parts of the book is intended largely as reference and outside reading or project reference reading. There are always some members of a class who have interests more keenly biological than others. It is thought that these pages may be particularly useful for such students. These pages will also be useful when they describe material that can be found locally and used in the laboratory.

ture of the group. They are animals in which the real body cavity is lacking, the animal in its simplest form being little more than a bag.

**Medusa.** — Among the most interesting of all the cœlenterates inhabiting salt water are the jellyfishes or medusæ. These animals vary greatly in size from a tiny umbrella-shaped form little larger than the head of a pin to huge jellyfishes several feet in diameter.




Medusa or jellyfish. Photograph from American Museum of Natural History.

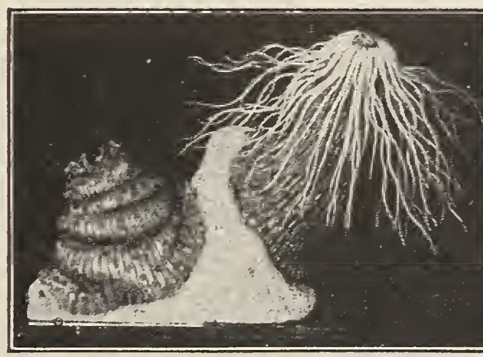



A hydroid colony of six polyps: *f*, feeding polyp; *r*, reproductive polyp; *m*, a medusa; *y*, young polyp.

**Development.** — Many species of medusæ pass through another stage of life. As medusæ they reproduce by eggs and sperms, that is, sexually. The egg of the medusa segments, forming ultimately a ball of cells (the *blastula*) which swims around by means of cilia. Ultimately the little animal settles down on one end and becomes fixed to a rock, seaweed, or pile. The free end becomes indented in the same manner as a hollow rubber ball may be pushed in on one side. This indented side becomes a mouth, tentacles develop around the orifice, and we have an animal that looks very much like the hydra. This animal, now known as a *hydroid polyp*, buds rapidly and soon forms a colony of little polyps, each of which is connected with its neighbor by a hollow food tube. The hydroid polyp differs from its fresh-water cousin, the hydra, by usually possessing a tough covering which is not alive.

**Alternation of Generations in Cœlenterates.** — The lives of a hydroid polyp and a medusa are seen thus to be intimately connected. A hydroid colony produces new polyps by budding. This is an *asexual* method of reproduction. There come from this hydroid colony, however, little buds which give rise to free-swimming medusæ. These medusæ produce eggs and sperms. Their reproduction is *sexual,* as was the reproduction by means of eggs and sperms from the prothallus of the fern. So we have in animals, as well as in plants, an alternation of generations.

**Sea Anemone.** — Those who have visited our New England coast are familiar with another cœlenterate called the *sea anemone* (a-nĕm′ō-nē). This animal gets its name because, when expanded, it looks like a beautiful flower of a golden yellow or red color. The body of the sea anemone is like the hydra, a column attached at one end. The free end is provided with a mouth surrounded with a great many tentacles. These, when expanded, look like the petals of a flower. The sea anemone is a very voracious animal, for by means of the batteries of stinging cells in its tentacles it is able to catch and devour fishes and other animals almost as large as itself. When disturbed, or irritated, the animal contracts into a slimy ball which is difficult to dislodge from its attachment.



Sea anemone. About one half natural size. The right-hand specimen is expanded. Note the mouth surrounded by the tentacles. The left-hand specimen is contracted. From model at the American Museum of Natural History.

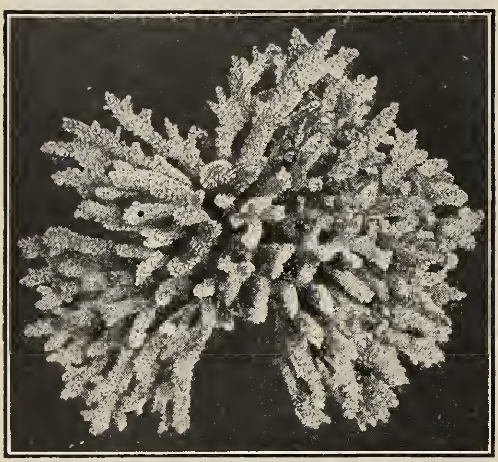
Although the sea anemone is like a large hydra in appearance, its interior is different. The hollow digestive cavity contains a number of partitions more or less complete, which run from the outer wall toward the middle of the cavity. These partitions, known as mes′enteries, are found in pairs. Part of the cavity, as in the hydra, is given up to digesting the food. Food is killed by means of stinging cells found in the long thread-like tentacles.

**Coral.** — If a piece of madrepor′ic coral is examined with a hand lens, a number of little depressions will be seen in the limy surface, each of which has tiny partitions within it. These cuplike depressions were once occupied by the coral animals of polyps, each in its own cup. The mesenteries of the coral polyp are paired and hollow on the under surface. The partitions seen in the coral cups lie between the pairs of mesenteries, and are formed by them when the animal is alive. Sea water has a considerable amount of lime in its composition. This lime (calcium carbonate) is taken from the water by certain of the cells of the coral polyp and deposited around

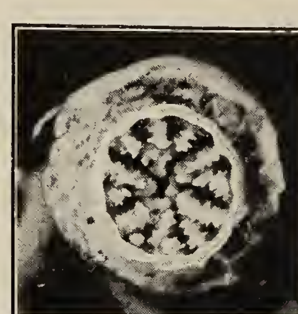
the base of the animal and between the mesenteries, thus giving the appearance just seen in the cups of the coral branch.

**Asexual Reproduction.** — These polyps reproduce by budding, and when alive cover the whole coral branch with a continuous living mass of polyps, each connected with its neighbor. In this way great masses of coral are formed. Coral, in a living state, is alive only on the surface, the polyps building outward on the skeleton formed by their predecessors.

**Economic Importance of Corals.** — Only one (*astrangia*) of a great many different species of coral lives as far north as New York. In tropical waters they are very abundant. Coral building has had and still has an immense influence on the formation of islands, and even parts of continents in tropical seas. Not only are many of the West Indian islands



A branching madreporic coral.



A single coral cup, showing the walls of lime built by the mesenteries. From a photograph loaned by the American Museum of Natural History.

composed largely of coral, but also Florida and many islands of the southern Pacific are almost entirely of coral formation.

**Coral Reefs.** — The coral polyps can live only in clear sea water of moderate depth. Fresh water, bearing mud or other impurities, kills them immediately. Hence coral reefs are never found near the mouths of large fresh-water rivers. Polyps are frequently found building reefs close to the shore. In such cases these reefs are called fringing reefs. The so-called barrier reefs are found at greater distance (sometimes forty to fifty miles) from the shore. An example is the Great Barrier Reef of Australia. The typical coral island is called an atoll. It has a circular form inclosing a part of the sea which may or may not be in communication with the ocean outside the atoll. The atoll was perhaps at one time a reef outside a small island. This island disappeared, probably by the sinking of the land. The polyps, which could live in water up to about one hundred and fifty feet, continued to build the reef until it rose to the surface of the ocean. As the polyps could not exist for long above low-waterline, the animals died and their skeletons became disintegrated by

the action of waves and air. Later birds brought a few seeds there, perhaps a coconut was washed ashore; thus plant life became established in the atoll, and a new outpost to support human life was established.

A Simple Classification of Cœlenterates

Class I. *Hydrozo'a.* A simple body cavity containing no mesenteries, usually alternation of generations. Examples: *Hydra*, hydroids.
Class II. *Scyphozoa* (sī-fo-zō'a). Example: large jellyfishes.
Class III. *Actinozo'a.* Mesenteries present in body cavity. Examples: sea anemones and corals.
Class IV. *Ctenophora* (tē-nŏf'o-ra).

**Summary.** — All animals develop from egg cells, which, after fertilization, go through a series of divisions. A hollow ball of cells (the blastula) is formed, and then a cup-shaped mass (the gastrula). Some animals such as the hydra stop their development at this stage; others reach a more complex adult stage.

The animals in the group cœlenterata have certain characteristics in common. One is the possession of stinging cells. Can you find any other characteristics which they all have?

Physiological division of labor has been shown to be the performance of different kinds of work by different collections of cells in an organism. This is shown in a simple way in the hydra.

**Problem Questions.** — 1. Compare reproduction in a simple plant and in a simple animal.

2. Describe the early stages of development in an animal.

3. Describe the structure of a simple sponge.

4. Compare the structure of a hydra and of a jellyfish.

5. Explain alternation of generations. Where have you found it before?

6. Discuss the economic importance of three animals mentioned in this chapter.

Problem and Project References

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## XVII. THE WORMS, A STUDY OF RELATIONS TO ENVIRONMENT

**Problem.** *To discover the relation of the earthworm to its surroundings. (Laboratory Manual, Prob. XXVII; Laboratory Problems, Prob. 118.)*

**Effect of Surroundings on Plants.** — Animals as well as plants are influenced very greatly by their surroundings or environment. We have seen how green plants behave toward the various factors of their environment; how heat and moisture start germination in a seed; how the roots grow toward water; how gravity influences the root and the stem, pulling the root downward and stimulating the stem to grow upward; how the stem grows toward the source of light; and how the leaves put their flat surfaces so as to get as much light as possible; and how oxygen is necessary for life to go on.

It is quite possible to show that the factors of environment act upon animals as well as plants, although it is much harder to explain why an animal does a certain thing at a certain time.

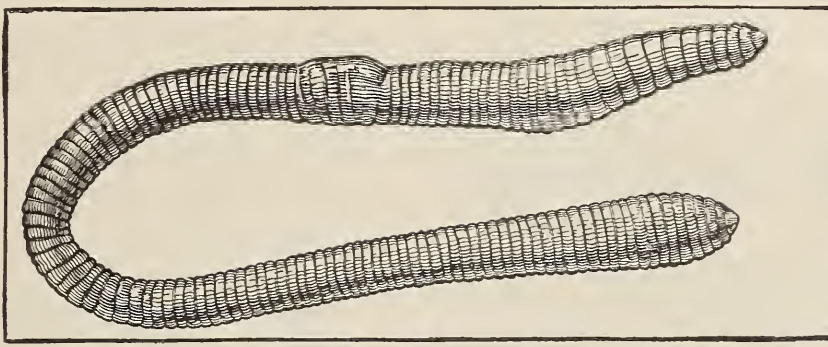
**How One-celled Animals respond to Stimuli.** — We have seen that the single-celled animals respond to certain stimuli in their surroundings. The presence of food attracts them; when they run into an object, they respond immediately by backing away, thus showing that they have a sense of touch. If part of a glass slide containing paramecia is heated slightly, the animals will respond to the increase in heat by moving toward the cooler end. Other experiments also might be quoted to show that the living matter of a simple animal is sensitive to its surroundings.

**The Earthworm in its Relation to its Surroundings.** — The earthworm, familiar to most boys as bait, shows us in many ways how a many-celled animal responds to stimuli. Careful observation of the body of a living earthworm reveals that its long tapering body is made up of a large number of rings

or *segments.* The number of these segments will be found to vary in worms of different lengths, the longer earthworms having more segments.

If the two ends of the earthworm be touched lightly with a small stick or straw, one end will be found to respond much more readily to touch than the other end. The more sensitive end is the front or *anterior* end; the other end is the *posterior* end. Jar the dish in which the earthworm is crawling; it will immediately respond by contracting its body.

Living earthworms tend to collect along the sides of a dish



An earthworm crawling over a smooth surface.

or in the corners. This seems to be due to an instinct which leads them to inhabit holes in the ground.

An earthworm placed half in and half out of the darkened area in a box soon responds by crawling into the darkened part and remaining there. It has no eyes visible. A careful study of the worm with the microscope, however, has revealed the fact that scattered through the skin, particularly of the anterior segments, are many little structures which enable the animal to distinguish not only between light and darkness, and between light of low and high intensity, but also the direction from which it comes. An earthworm has no ears or special organs of feeling. We know, however, that it responds to vibrations of low intensity, and the sense of touch is well developed in all parts of its body.

It also responds to the presence of food, as can be proved if bits of lettuce or cabbage leaf are left overnight in a dish of earth where earthworms are kept.

**Locomotion of an Earthworm.** — If we measure an earthworm when it is extended and compare with the same worm contracted, we note a difference in length. This is accounted for when we understand the method of locomotion. Under the skin are two sets of muscles, an outer set which passes in a circular direction around the body, and an inner set which runs the length of the body. The body is lengthened by the contraction of the circular muscles. How might the body be shortened?

The under surface of the earthworm is provided with four double rows of tiny bristles called *se'tæ*, on all the segments except the first three and the last. Each seta has attached to it small muscles, which turn it so it may point in the direction opposite to that in which the worm is moving. If you watch a specimen carefully, you will see that locomotion is accomplished by the thrusting forward of the anterior end, followed by a wave of muscular contraction passing down the body, thus shortening the body by drawing up the posterior end. The setæ at the anterior end serve as anchors which prevent the body from slipping backward as the posterior end is drawn up.

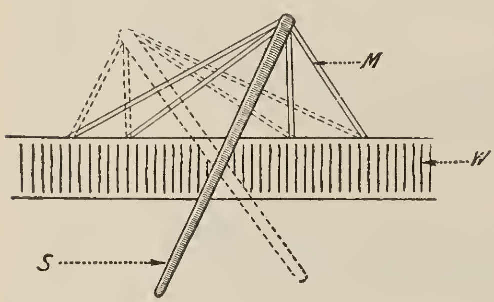
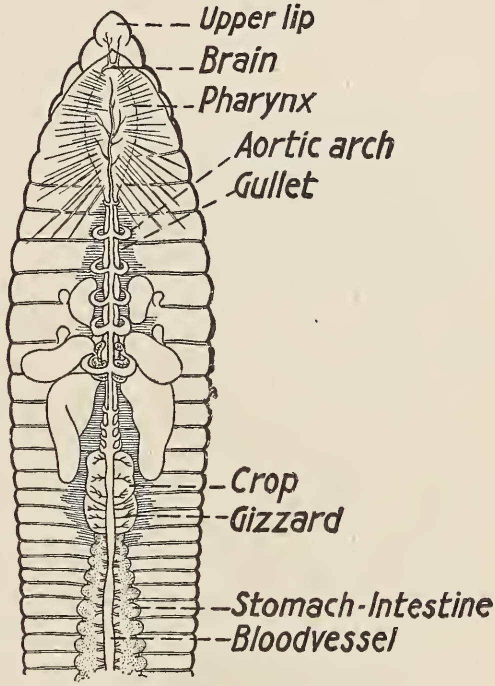


Diagram to show how movement of a seta is accomplished; *M*, muscles; *S*, seta; *W*, body wall. (After Sedgwick and Wilson.)

**How the Earthworm digs Holes.** — A feeding earthworm will show the *prosto'mium*, an extension of the upper lip which is used as an organ of sensation. The earthworm is not provided with hard jaws or teeth. Yet it literally eats its way through the hardest soil. Behind the mouth opening is a part of the food tube called the *phar'ynx*. This is very muscular so that it can be extended and withdrawn by the earthworm. When applied to the surface of the soil, which is first moistened by the earthworm, it acts as a suction pump and draws particles of the soil into the food tube. In order to take organic matter out of the ground as food, the earthworms pass the earth through the body. The earth

is mixed with fluids poured out from glands in the food tube, which digest the food, and the soil is passed out of the body and deposited on the surface of the ground, in the form of little piles of moist earth. These are familiar sights on all lawns; they are called worm casts. Charles Darwin calculated that fifty-three thousand worms may be found in an acre of ground, that ten tons of soil might pass through their bodies in a single year and thus be brought to the surface, and that they plow more soil than all the farmers put together.




Fore part of an earthworm opened on the dorsal side to show the body cavity and food tube within it.

**Comparison between Hydra and Earthworm.**—The digestive tract of the earthworm is an almost straight tube inside of another tube. The latter is divided by partitions which mark the boundary of each segment. The outer cavity is known as the *body cavity*. In the hydra no body cavity exists, there being only a digestive cavity. In the animals higher than the cœlenterates the digestive tract and body cavity are distinct. Food is digested within the food tube, is passed through the walls of this tube into the body cavity, and is carried by the blood to various parts of the body. The earthworm has no gills or lungs, the thin skin acting as an organ of respiration. But the earthworm is unable to take in oxygen unless the membranelike skin is kept moist.


Diagrammatic cross section of the body of a cœlenterate, and that of a worm.

**Development.**—The earthworm has both male and female sex cells present in its body and hence is said to be *hermaphro-dit'ic* (from Hermes and Aphrodite). In order to have the eggs

fertilized when they are laid a mutual exchange of sperm cells takes place between two worms, the sperms being placed in four little sacs on the ventral side of each worm. Later the swollen area called the *girdle* (about one third the distance from the anterior end) forms a little sac in which the eggs of the worm are laid. As this sac passes toward the anterior end of the earthworm it receives from the body openings the sperms which were received from the other earthworm and a nutritive fluid in which the eggs live. The fertilized eggs are then left to hatch. The sacs or capsules may be found in manure heaps, or under stones, in May or June; they are small yellowish or brown bags about the diameter of a worm.

**Regeneration.** — If a one-celled animal be cut into two pieces, each piece, if it contains part of the nucleus, can grow into a whole cell. The hydra, some hydroids, jellyfish, and flatworms, if injured, may grow again parts that are lost. This power is known as *regeneration*. Earthworms possess to a large degree the power of replacing parts lost through accident or other means. The anterior end may form a new posterior end, while the posterior end must be cut anterior to the girdle to form a new anterior end. This difference seems to be due in part to the greater complexity of the organs in the anterior end.

**Other Segmented Worms.** — The sandworm, living on tidal flats along our eastern coast, is a common sight to those who live in that region. The leech or bloodsucker is a form known to every small boy who has bathed in a fresh-water pond. Discomfort, but no danger, attends the bite of this worm.

**Problem.** *To determine some harmful animal associations.* (*Laboratory Manual, Prob. XXVIII.*)

**Some Worms which harm Man.** — Some worms are unsegmented; such are the flatworms and roundworms. A common leaflike form of flatworm may be found clinging to stones in our fresh-water ponds or brooks. Most flatworms are, however, *parasites* on other animals; that is, they obtain food and shelter from some other living creature, but give it no benefits in return. Parasitism is one-sided, the host giving everything, the parasite receiving everything. Consequently, the parasite

frequently becomes fastened to its host during adult life and often is reduced to a mere bag through which the fluid food prepared by its host is absorbed. Such animals as have lost power to move about freely, to digest food, or to perform some other function as a result of their comfortable surroundings, are said to have *degenerated*.

A flatworm (*Yungia aurantiaca*), much magnified. From model in the American Museum of Natural History.

Sometimes a complicated life history has arisen from parasitic habits. Such is seen in the life history of the liver fluke, a flatworm which kills sheep, and in the tapeworm.

**Cestodes or Tapeworms.** — These parasites infest man and many other vertebrate animals. The tapeworm (*Tænia solium*) passes through two stages in its life history, the first within a pig, the second within the intestine of man. The eggs of this worm are taken in with the pig's food. The young worm develops within the intestine of the pig, but soon makes its way into the muscles. When man eats pork containing tapeworms, if the pork has not been sufficiently cooked, he may become a host for the tapeworm. Another common tapeworm parasitic on man lives part of its life as an embryo within the muscles of cattle. The adult worm consists of a round headlike part provided with hooks, by means of which it fastens itself to the walls of the intestine. This head now buds off a series of segmentlike structures, which are practically bags full of eggs. These structures, called *proglot'tids*, break off from time to time, thus allowing the eggs to escape. A proglottid has no separate digestive system, but the whole body surface is bathed in digested food, which it absorbs and thus the parasite is enabled to grow rapidly.

**Roundworms.** — Still other wormlike creatures called roundworms are of importance to man. Some, as the vinegar eel found in vinegar, or the pinworms parasitic in the lower intestine, particularly of children, do little or no harm. The pork worm or *trichina* (trĭ-kī'na), however, is a parasite which may cause serious injury. It passes through the first part of its

existence as a parasite in a pig or other vertebrate (as a cat, rat, or rabbit), where it encysts itself in the muscles of its hosts. If the meat is eaten in an uncooked condition, the cyst is dissolved off by the action of the digestive fluids, and the living trichina becomes free in the intestine. Here it bores its way through the intestinal walls and enters the muscles, causing inflammation. This results in a painful and often fatal disease known as *trichino'sis*.

Effect of hookworm infection. The young man at the left, 17 years old, weighs 156 pounds. His older brother beside him, 18 years of age, badly infected with hookworm, weighs only 74 pounds.

**The Hookworm.** — The account of the discovery by Dr. C. W. Stiles of the Bureau of Animal Industry, that the shiftlessness of the "poor whites" of the South is due partly to a parasite called the *hookworm*, another roundworm, reads like a fairy tale.

The people, largely farmers, become infected with a larval stage of the hookworm, which develops in moist earth. It enters the body usually through a break in the skin of the feet, for children and adults alike, in certain localities where the disease is common, go barefoot to a considerable extent.

A complicated journey from the skin to the intestine now follows. The larvæ pass through the veins to the heart, and from there to the lungs. They then bore into the air passages and eventually reach the intestine by way of the windpipe. One result of the injury to the lungs is that many thus infected are subject to tuberculosis. The adult hookworms, once in the food tube, fasten themselves to the walls, which they puncture, and

feed upon the blood of their host. The loss of blood from this cause is not sufficient to account for the bloodlessness of the person infected, but a poison poured into the wound by the hookworm prevents the blood from coagulating rapidly; hence a considerable amount of blood escapes from the wound after the hookworm has finished its meal and gone to another part of the intestine.

The cure of the disease is very easy: thymol, which weakens the hold of the hookworm, followed by Epsom salts. For years the entire South undoubtedly has been retarded in its development by this parasite. Hundreds of millions of dollars have been wasted, and, what is more vital, thousands of lives have been needlessly sacrificed.

"The hookworm is not a bit spectacular: it doesn't get itself discussed in legislative halls or furiously debated in political campaigns. Modest and unassuming, it does not aspire to such dignity. It is satisfied simply with (1) lowering the working efficiency and the pleasure of living in something like two hundred thousand persons in Georgia and all other Southern states in proportion; with (2) amassing a death rate higher than tuberculosis, pneumonia, or typhoid fever; with (3) stubbornly and quite effectually retarding the agricultural and industrial development of the section; with (4) nullifying the benefit of thousands of dollars spent upon education; with (5) costing the South, in the course of a few decades, several hundred millions of dollars. More serious and closer at hand than the tariff; more costly, threatening, and tangible than the Negro problem; making the menace of the boll weevil laughable in comparison — it is preeminently the problem of the South." — *Atlanta Constitution.*

The work of the Rockefeller Foundation in the tropics has proved that the hookworm is found in most hot and moist climates and that consequently natives of such countries are often attacked by it. It is thought that 75 per cent of the natives of Southern China, 60 to 80 per cent of 300,000,000 natives of India and over 90 per cent of the laboring classes of Dutch Guiana and Colombia are infected with it, while over 2,000,000 people in this country are its victims. If we were to estimate the economic loss due to hookworm the world over, it would run into hundreds of millions of dollars annually.

**Other Parasitic Worms.** — Some roundworm parasites live in

the skin, and others live in the intestines of the horse. Still others are parasitic in fish and in insects, one of the commonest being the hair snake, often seen in country brooks.

### A Simple Classification of Worms

#### A. Segmented Worms (Annula'ta)

Class I. *Chætopoda* (kē-tŏp'o-da; bristle-footed). Segmented worms having setæ.

Subclass I. *Polychæta* (pŏl-ĭ-kē'ta; many bristles). Having parapodia, and usually head and gills. Example: sandworm.

Subclass II. *Oligochæ'ta* (ŏl-i-go-kē'ta; few bristles). No parapodia, head, or gills. Example: earthworm.

Class II. *Discophora* (dĭs-kŏf'ŏ-ra; bearing suckers). No bristles, two sucking disks present. Example: leech.

#### B. Flatworms

Body flattened in dorso-ventral direction

Class I. *Turbella'ria.* Small, aquatic, mostly not parasitic. Example: planarian worm.

Class II. *Tremato'da.* Usually parasitic worms which have complicated life history. Example: liver fluke of sheep.

Class III. *Cesto'da.* Internal parasites having two hosts. Example: tapeworm.

#### C. Roundworms

Threadlike worms, mostly parasitic. Examples: vinegar eel, trichina, and hookworm.

**Summary.** — The earthworm is a simple type of a *segmented* worm. One of its most important differences from the hydra lies in its possession of a body cavity as well as a digestive cavity.

Parasitic worms such as the tapeworm, trichina, and hookworm play an important economic part in the life of today. Thanks to the work of the Rockefeller Foundation and other agencies, hookworm disease is fast being reduced in all civilized parts of the earth.

**Problem Questions.** — 1. How is the earthworm of economic importance?

2. Describe the internal structure of the earthworm and tell the use of each part named.

3. Discuss the life history of some parasitic worm and show how its harmfulness may be combated.

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## XVIII. THE CRAYFISH. A STUDY OF ADAPTATIONS

**Problem.** *A study of the meaning of the term of adaptation as shown in the crayfish.* (*Laboratory Manual, Prob. XXIX; Laboratory Problems, Prob. 118.*)

(*a*) *Protection.*
(*b*) *Locomotion.*
(*c*) *Feeding.*
(*d*) *Breathing.*

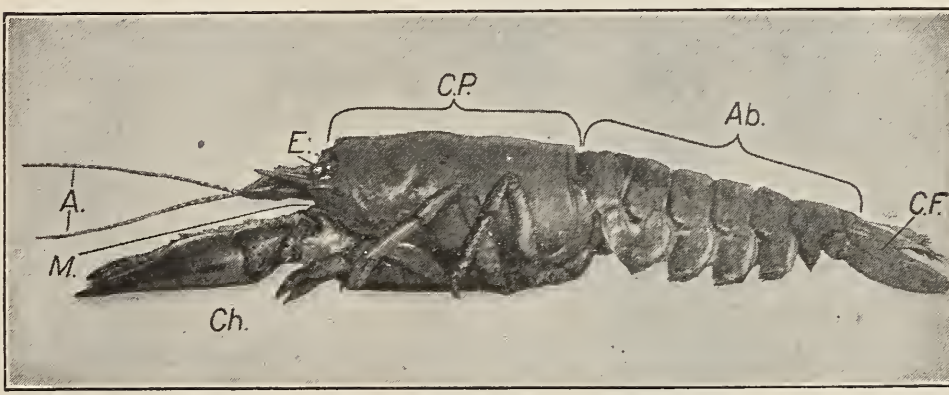
**Adaptations.** — Plants and animals are in a continual struggle to hold the places they have obtained upon the earth. Continually we see garden plants driven out or killed by the competing weeds, simply because the weeds are better fitted or *adapted* to live under the conditions which exist in the garden, especially if it is uncultivated. An adaptation in a plant or animal is some change in structure, habit, or ability which is of advantage to the organism in its battle for life. We have seen many examples of adaptations in plants, — adaptations in flowers for securing cross-pollination, in fruits for seed-scattering, in young plants for protection, in roots for securing water; the list is endless.

In animals, likewise, the successful competitors are the ones with adaptations to fit them for living in the particular environment or surroundings in which nature has put them. Examples are often seen where animals, like sheep or goats, which have a woolly covering, when introduced by man into a warmer country, die because the outer coat is too warm. An adaptation for withstanding cold becomes harmful to the animal in a warmer country.

One adaptation which we have already noticed in animals is always protective. This is the resemblance of the animal to the surroundings in which it lives. Other adaptations aid the animal in obtaining and digesting food, in protecting itself or its

young from attacks by enemies, and in battling successfully with the dangers around it.

**The Crayfish. Adaptations for Protection.** — Animals which illustrate adaptations for life in the water are the fresh-water crayfish and the salt-water lobster, both members of a large group of animals known as *crusta'ceans*. The body of one of these animals is seen to be encased more or less completely in a hard covering, which is jointed in the posterior region. This *exoskeleton* (outside skeleton) is composed largely of lime, as may be proved by testing with acid. The exoskeleton fits over the anterior part of the animal, forming an unjointed *car'apace*,




Crayfish: *A.*, antennæ; *E.*, stalked eye; *C.P.*, cephalothorax; *Ab.*, abdomen; *C.F.*, caudal fin; *M.*, mouth; *Ch.*, chelipeds. From photograph.

or armor. This armor is clearly protective and is therefore an adaptation. If the crayfish is watched in a balanced aquarium, the colors are seen to blend remarkably with the stones and water weeds of the bottom. The animal is protectively colored. The under side of the animal is less well protected than the upper, and the joints of the *abdo'men*, or posterior region, extend completely around the body. The animal is *segmented*, the abdomen showing the segments plainly.

**Locomotion.** — Those of us who have caught crayfish in fresh-water streams or lakes know that it takes skill and quickness. They dart backwards through the water with great rapidity, or they move forward by crawling on the bottom. Examination of a crayfish shows us five pairs of walking legs attached to the under side of the *cephalotho'rax* (head + thorax), the

anterior part of the body. These legs are jointed, and the first three pairs bear pinchers. The large pincher claws or *chelipeds* (kē′lĭ-pĕdz) are used for food-catching as well as for locomotion. Try to find out exactly what their use is in a living specimen.

Under the abdomen, one pair on each segment except the last, are found jointed appendages, made up of three parts, a base and two branches. These are called *swimmerets,* though they are *not* used for swimming. Now look at the broad pair of swimmerets which, together with the last segment of the abdomen, form a finlike apparatus, the *caudal fin.* Crayfish swim very rapidly by means of a sudden jerking of the caudal fin in a backward direction. The abdomen is provided with powerful muscles which are attached to the exoskeleton. It is by these muscles that the rapid swimming is accomplished.

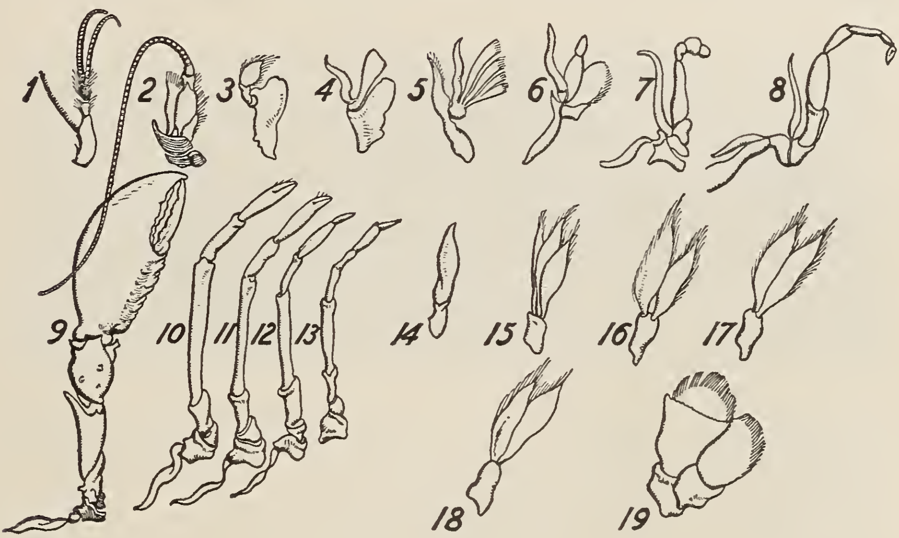
Female lobster, showing eggs attached to the swimmerets. From photograph loaned by the American Museum of Natural History.

**How the Crayfish gets in Touch with its Surroundings.** — Several other appendages besides those used for locomotion are found. Two pairs of "feelers," the longer pair called the *anten′næ,* the shorter the *anten′nules* (little antennæ), protrude from the front of the body. The longer feelers appear to be used as organs of touch and smell. The smaller antennules hold at their bases little sacs called *balancing organs.*

Just above the antennules, projecting on stalks, are the eyes. These eyes are made up of many small structures called *om-*

*matid'ia,* each one of which is a very simple eye. A collection of ommatidia is known as a *compound eye.* Such an eye probably does not have very distinct vision. A crayfish, however, easily distinguishes moving objects and prefers darkness to light, as may be proved by experiment.

**Feeding.** — Living food is obtained with the aid of the chelipeds and shoved toward the mouth. It is pushed on by three pairs of small appendages called foot jaws or *maxil'lipeds,* and




Appendages of the crayfish: *1*, antennule; *2*, antenna; *3*, mandible; *4*, first maxilla; *5*, second maxilla; *6*, first maxilliped; *7*, second maxilliped; *8*, third maxilliped; *9*, cheliped; *10*, *11*, *12*, *13*, walking legs; *14*, modified swimmeret in male; *15*, modified swimmeret in male; *16*, *17*, *18*, swimmerets which carry the eggs in female; *19*, uropod, the side part of the caudal fin.

to a slight degree by two still smaller paired *maxil'læ* just under the maxillipeds. Ultimately the food reaches the hard *jaws* and, after being ground between them, is passed down to the stomach.

**Experiment to demonstrate Breathing.** — The mouth parts of a crayfish resting in the aquarium are observed to be constantly in motion, despite the fact that no food is present. If a crayfish is taken out of the water and held with the ventral surface uppermost, a little carmine (mixed in water) may be dropped on the lower surface and allowed to run down under the carapace. If the animal is now held in water in the same position, the carmine will reappear from both sides of the mouth, seemingly pro-

pelled forward by something which causes it to emerge in little puffs. If we remove the maxillipeds and maxillæ from a dead specimen, we find a groove leading back from each side of the mouth to a cavity of considerable size on each side of the body under the carapace. This is the *gill chamber*. It contains the *gills*, the organs which absorb the oxygen dissolved in the water. The second maxillæ are prolonged into the groove to serve as bailers or scoops. By rapid action of these organs a current of water is maintained which passes over the gills.

**The Gills.** — The gills are outside of the body, although protected by the carapace. If the carapace is partly removed on


Crayfish with the left half of the body structures removed: *a*, intestine; *b*, ventral artery; *c*, brain; *e*, heart; *et*, gastric teeth; *i*, oviduct; *l*, digestive gland; *m*, muscles; *n*, green gland (kidney); *o*, ovary; *p*, pyloric stomach; *r*, nerve cords; *s*, cardiac stomach; *st*, mouth; *u*, telson, or last segment of the abdomen, forming the middle part of the caudal fin; *w*, openings of veins into the pericardial sinus. Natural size. (Davison, *Zoölogy*.)

one side, they will be found looking somewhat like white feathers. The blood of the crayfish passes by a series of veins into the long axis of the gill, where the blood vessels divide into very minute tubes, the walls of which are extremely delicate. Oxygen, dissolved in the water, passes into the blood by osmosis, during which process the blood loses some carbon dioxide. The gills are kept from drying by being placed in a nearly closed chamber, which has a row of tiny hairs bordering the lower edge of the carapace. Thus crayfish may live for long periods away from water.

**Circulation.** — The circulation of blood in the crayfish takes place in a system of thin-walled, flabby vessels which are open in places, allowing the blood to come in direct contact with the tissues to which it flows. The heart lies on the dorsal side of the body, inclosed in a delicate bag,

into which all the blood in the body eventually finds its way during its circulation.

**Digestion.** — Food which has not been ground up previously into pieces small enough for the purpose of digestion is still further masticated by means of three strong projections or teeth, one placed on the mid-line and two on the side walls of the stomach. The exoskeleton of the crayfish extends into the stomach, thus forming the *gastric mill* just described.

The stomach is divided into anterior and posterior parts separated from each other by a constriction. The posterior part is lined with tiny projections from the walls which make it act as a strainer for the food passing through. Thus the larger particles of food are kept in the anterior end of the stomach. Opening into the posterior end of the stomach are two large digestive glands whose juices further prepare the food for absorption through the walls of the intestine. Once in the blood, the fluid food is circulated through the body to the tissues which need it.

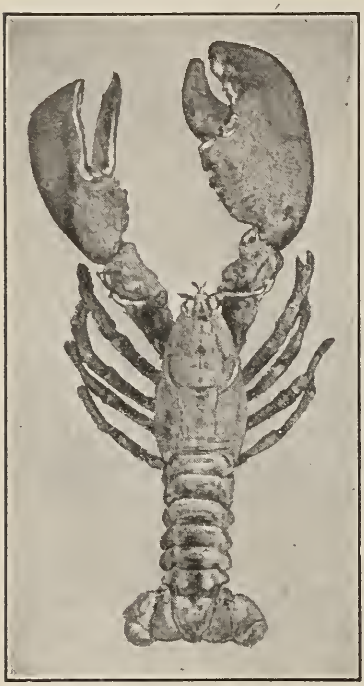
**Nervous System.** — The internal nervous system of a crayfish consists of a series of collections of nerve cells called *ganglia* (găng'glĭ-a) connected by means of a double line of nerves. Posterior to the gullet, this chain of ganglia is found on the ventral side of the body, near the body wall. At the anterior end it encircles the gullet and forms a brain in the head region, from several ganglia which have grown together. From each of these ganglia, nerves pass off to the sense organs and into the muscles of the body. These nerve fibers are of two sorts, those bearing messages from the outside of the body to the central nervous system (these messages result in sensations), and those which take outgoing messages from the central nervous system (motor impulses), which result in muscular movements.

**Development.** — The sexes in the crayfish are distinct. The eggs are fertilized by the sperm cells as they pass to the outside of the body of the female. The eggs, which are provided with a considerable supply of food material called yolk, are glued fast to the swimmerets of the mother, and there develop in safety. The young, when they first hatch, remain clinging to the swimmerets for several weeks.

**Excretion of Wastes.** — On the basal joint of the antennæ are found two projections, in the center of which are tiny holes. These are the openings of the *green glands*, organs which eliminate the nitrogenous waste from the blood, the function of the human kidneys.

**North American Lobster.** — In structure the lobster is almost the counterpart of its smaller cousin, the crayfish. Its geographical range is a strip of ocean bottom along our coast, estimated to vary from thirty to fifty miles in width. This strip extends from Labrador on the north to Delaware on the south. The lobster is highly sensitive to changes in temperature. It mi-

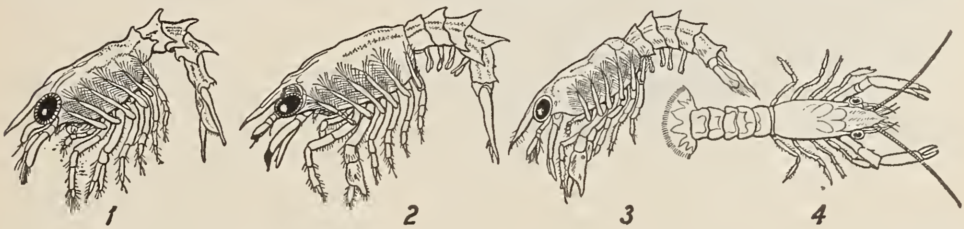
grates from deep to shallow water, or *vice versa,* according to changes in the temperature of the water, which in winter is relatively warmer in deep water and cooler in shallows. Sudden changes in the temperature of the water of a given locality may cause them to disappear from that place. The food supply which is more abundant near the shore also aids in determining the habitat of the lobster. Lobsters do not appear to migrate north and south along the coast. While little is known about their habits on the ocean bottom, it is thought that they construct burrows somewhat like the crayfish, in which they pass part of the time. As they are the color of the bottom and as they pass much of their time among the weed-covered rocks, they are able to catch much living food, even active fishes falling prey to their formidable pinchers. They move around freely at night, usually remaining quiet during the day, especially when in shallow water. They eat some dead food and thus are scavengers; the same is true of the crayfish.



North American lobster. This specimen, preserved at the U. S. Fish Commission at Woods Hole, was of unusual size and weighed over twenty pounds. Notice the chelipeds.

**Development.**—The female lobsters begin to lay eggs when about seven inches in length. Lobsters of this size lay nearly five thousand eggs; this number is increased to about ten thousand by lobsters of moderate size (ten inches in length); by exceptionally large specimens as many as one hundred thousand eggs are sometimes laid. The eggs are laid every alternate year, usually during the months of July and August. Eggs laid in these months, as shown by observations made along the coast of Massachusetts, hatch the following May or June. The eggs are provided with a large supply of yolk (food), the development of the young animal taking place at the expense of this food material. After the young escape

from the eggs, they are almost transparent and little like the adult in form. During this period of their lives the mortality is very great, as they are the prey of many fish and other free-swimming animals. It is estimated that barely one in five thousand survives this period of peril. At this time they grow rapidly, and in consequence are obliged to shed their exoskeleton




Metamorphosis of a lobster: 1, 2, 3, larval stages; 4, very young lobster in its adult form.

(molt) frequently. During the first six weeks of life, when they swim freely at the surface of the water, they molt five or six times.[1]

**Molting.** — During the first year of its life the lobster molts from fourteen to seventeen times. During this period it attains a length of from two to three inches. Molting is accomplished in the following manner: The carapace is raised up from the posterior end and the body is then withdrawn through the opening between it and the abdomen. The most wonderful part of the process is the withdrawal of the flesh of the large claws through the very small openings which connect the limbs with the body. The blood is first withdrawn from the appendage; this leaves the flesh in a flabby, shrunken condition so that the muscles can be drawn through without injury. The lobster also molts the lining of the digestive tract as far as the posterior portion of the stomach. Immediately after molting the lobster is in a helpless condition, and is more or less at the mercy of its enemies until the new shell, which is secreted by the skin, has grown.

[1] Recent economic investigations upon the care of young lobsters show that animals protected during the first few months of free existence have a far better chance of becoming adults than those left to grow up without protection. Later in life they sink to the bottom, where, because of their protectively colored shell and the habit of hiding under rocks and in burrows, they are comparatively safe from the attack of enemies.

**Economic Importance.** — The lobster is highly esteemed as food, and is rapidly disappearing from our coasts as the result of overfishing. Between twenty million and thirty million a year are taken on the North Atlantic coast. Laws have been enacted in New York and other states against overfishing. Egg-carrying lobsters must be returned to the water; all smaller than six to ten and one half inches in length (the law varies in different states) must be put back; other restrictions are placed upon the taking of the animals, in hope of saving the race from extinction. Some states now hatch and care for the young for a period of time; the United States Bureau of Fisheries is also doing much good work, in hope of restocking to some extent the now almost depleted waters.

The edible blue crab. From photograph loaned by the American Museum of Natural History.

**Shrimps.** — Several other common crustaceans are near relatives of the crayfish. Among them are the shrimps and prawns, thin-shelled, active crustaceans common along our eastern coast. In spite of the fact that they form a large part of the food supply of many marine animals, especially fishes, they do not appear to be decreasing in numbers. Besides this value as a food for fishes, they are also used by man, the shrimp fisheries in this country aggregating over $1,000,000 yearly.

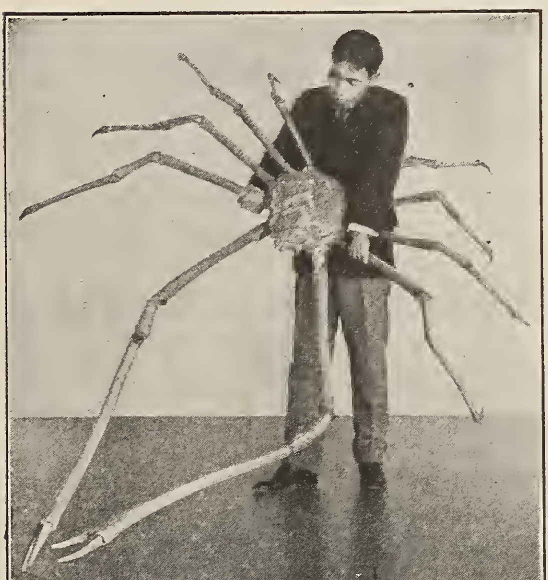
Hermit crab, about twice natural size. From photograph loaned by the American Museum of Natural History.

**The Blue Crab.** — Another edible crustacean of considerable economic importance is the blue crab. Crabs are found inhabiting muddy bottoms; in such localities they are caught in great numbers in nets or traps baited with decaying meat. They are, indeed, among our most valuable sea scavengers, although they are also hunters of living prey. The ante-

rior part of the body of the crab is short and broad, being flattened dorso-ventrally. The abdomen is much reduced in size. Usually it is carried close to the under surface of the cephalothorax. In the female the eggs are carried under the ventral surface of the abdomen, fastened to the rudimentary swimmerets in the position which is usual for other crustaceans. The young crabs differ considerably from the adult in form and method of life. They undergo a complete *metamor'phosis* or change of form during development. Immediately after molting, crabs are greatly desired by man as an article of food. They are then known as "shedders," or soft-shelled crabs.

The fiddler crab. From photograph loaned by the American Museum of Natural History.

**Other Crabs.** — Other crabs found along the New York coast are the prettily colored lady crabs, often seen running along our sandy beaches at low tide; the fiddler crabs, interesting because of their burrows and gregarious habits; and perhaps most interesting of all, the hermit crabs. The hermit crabs use the shells of snails as homes. The abdomen is soft, and unprotected by a limy exoskeleton, and has adapted itself to its conditions by curling around in the spiral snail shell, so that it has become asymmetrical. These tiny crabs are great fighters and wage frequent duels with each other for possession of the more desirable shells. They exchange their borrowed shells for larger ones as growth forces them from their first homes.



Giant spider crab from Japan. From photograph loaned by the American Museum of Natural History.

The habits of these animals, and those of the fiddler crabs, might be studied with profit by some careful boy or girl who spends a summer at the seashore and has the time and inclination to devote to the work. Of especial interest would be a study of the food and feeding habits of the fiddler crabs.

A deep-water crab often seen along Long Island Sound is the spider crab, or "sea spider," as it is incorrectly called by fishermen. This ani-

mal, with its long spider-like legs, is neither an active runner nor swimmer; it is, however, colored like the dark mud and stones over which it crawls; thus it is enabled to approach its prey without being noticed. The resemblance to the bottom is further heightened by the rough body covering, which gives a hold to which seaweeds and sometimes such animals as barnacles, hydroids, or sea anemones fasten themselves.

A spider crab from the Sea of Japan is said to be the largest crustacean in the world, some specimens measuring eighteen feet from tip to tip of the first pair of legs.

**Symbiosis.** — Certain of the spider crabs, as well as some of the larger deep-water hermit crabs, have come to live in a relation of mutual helpfulness with hydroids, sponges, and sea anemones. These animals attach themselves to the shell of the crab and are carried around by it, thus receiving a constant change of location and a supply of food. What they do for the crab in return is not so evident, although one large Chinese hermit crab regularly plants a sea anemone on its big claw; when forced to retreat into its shell, the entrance is thus effectually blocked by the anemone. The living of animals in a mutually helpful relation has been referred to as *symbiosis*. Of this we have already had some examples in plants as well as among animals. (See page 169.)

**Habitat.** — Most crustaceans are adapted to live in the water; a few forms, however, are found living on land. Such are the wood lice, the pill bugs, which have the habit of rolling up into a ball to escape attack of enemies, the beach fleas, and others. The coconut crab of the tropics climbs trees in search of food, returning to the water at intervals to moisten the gills.

**Characteristics of Crayfish and its Allies.** — Our study shows us that animals belonging to the same group have several well-marked characteristics in common. The most important characteristic of the *crusta'cea*, the group to which the crayfish belongs, are the presence of a segmented limy exoskeleton, gills, jointed appendages, usually a pair to each segment of the body (except the last), stalked compound eyes, and the fact that they pass through a *metamorphosis* or change of form before they reach the adult state.

**Summary.** — The crayfish has been used in this chapter to give us some idea of its numerous adaptations. These have

to do with its method of locomotion, feeding, breathing, in fact all of its activities. Acts which tend to the preservation of the race may be adaptive as well as structures which have this purpose.

**Problem Questions.** — 1. Explain what is meant by the term adaptation.

2. Name and describe adaptations in the crayfish for protection, feeding, breathing, locomotion, digestion.

3. Is molting an adaptation? Explain.

4. Discuss the life history of the lobster.

5. Discuss the economic importance of the crustacea.

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## XIX. THE INSECTS

**Problem.** *A study of some animal likenesses and differences in order to understand an elementary classification of insects. (Laboratory Manual, Prob. XXX; Laboratory Problems, Probs. 8, 9, 10, 11.)*

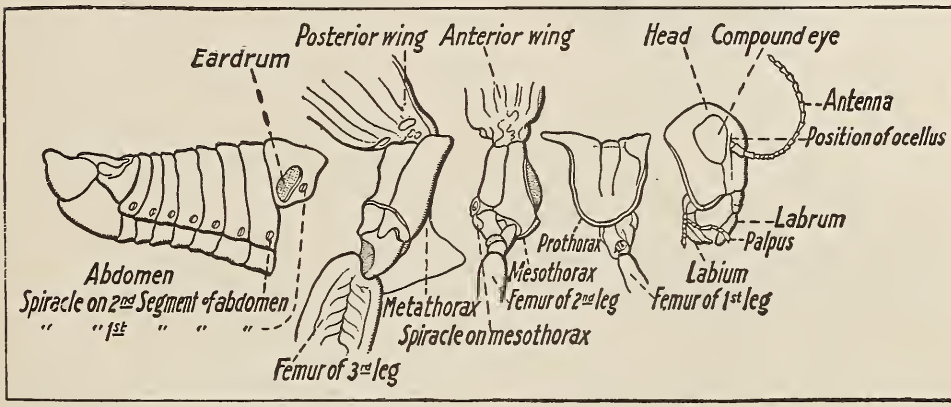
(*a*) *Grasshopper — a straight-winged insect.*
(*b*) *Butterfly or moth — a scale-winged insect.*
(*c*) *The typhoid fly — a two-winged insect.*
(*d*) *A beetle — a sheath-winged insect.*
(*e*) *A bug — a half-winged insect.*
(*f*) *The dragon fly — a nerve-winged insect.*
(*g*) *The bee — a membrane-winged insect.*
(*h*) *Summary of differences between orders.*
(*i*) *Making a logical definition.*

**Insects the Winners in Life's Race.**— We are all familiar with common examples of insect life. Bees and butterflies we have already studied in connection with their work in the cross-pollination of flowers. Mosquitoes and flies all too often come to our notice as pests; the common household insects sometimes annoy us, while we often hear of and see in a small way the harm done by insects in the field and garden. Insects are a successful group. They outnumber all the other species of animals on the face of the earth. They hold their own in the air, in the water, and on the land. Fitted in many ways to lead a successful life, they have become winners in life's race.

We have already, from our study of a bee, formed some idea of what an insect is. But it would be unfair to expect to know *all* insects from our slight knowledge of one form. Our object in the study of this chapter will be to get some first-hand knowledge of some common insects so that we may classify them and distinguish one from another. This great group, containing more than half of the known representatives of animal life on the earth, is made up of a number of groups

called *orders.* The insects contained in these orders have certain characteristics of structure and life history in common, yet each order differs somewhat from the other orders. The characteristics which *all* the groups possess in common give us a working definition of an insect.

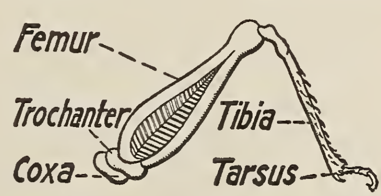
**The Red-legged Grasshopper.** — One of the most common insects in the United States is the red-legged grasshopper. Its




Parts of the body of a male grasshopper.

segmented body is divided into an anterior part, the *head;* a middle portion, the *tho'rax;* and a posterior portion, the *abdomen.* The animal is nearly the color of the grass on which it lives. The tough exoskeleton covering the body is composed of *chitin* (kī'tĭn), a substance somewhat like that which forms the horns of a cow.

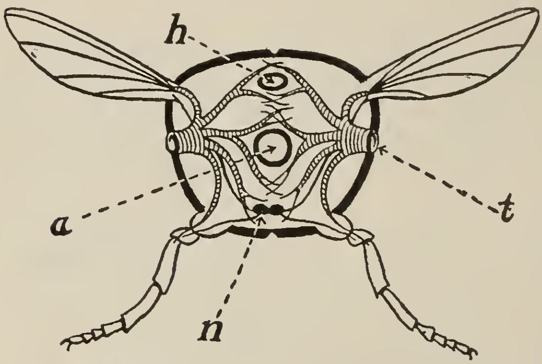
**The Thorax.** — The thorax is formed of three segments, the most anterior of which is known as the *protho'rax,* the middle one as the *mesothorax,* and the posterior part as the *metathorax.* Each segment bears a pair of jointed legs, and the posterior two segments bear wings also.




Hind leg of a grasshopper.

**The Legs.** — The legs, six in number, are fitted for active life in the fields. A careful study of the insect shows the hind leg to be fitted for jumping, not only in structure but also in position. It is long, jointed, and attached to powerful muscles which enable the grasshopper to spring forward quickly to

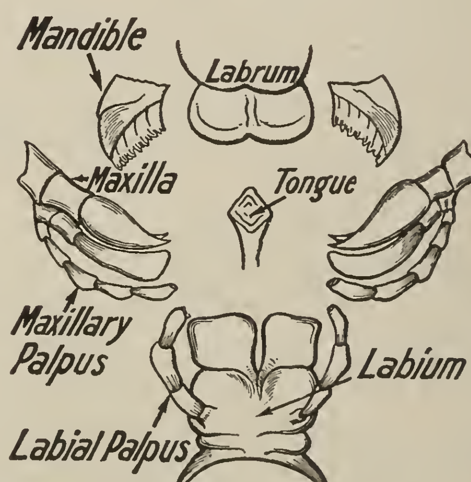
a great distance when the size of its small body is considered. An examination of the foot or *tarsus* shows a number of tiny hooks and pads, by means of which the insect can cling to the swaying grass stalks. Study the other legs and see if you can find similar adaptive structures.




Cross section through the body of an insect: *a*, food tube; *h*, heart; *n*, nerve cord; *t*, spiracle, opening of trachea.

**The Wings.** — The membrane-like wings, when spread out, show differences in structure. The outer pair, stronger and narrower than the inner pair, serve to protect the latter. The inner wings, when not in use, fold up like a fan.

**The Abdomen.** — The segmented abdomen does not bear appendages, but at the posterior end of the abdomen of the female are found paired movable pieces which together form the egg layer or *ovipos'itor.* The male grasshopper has a rounded abdomen.




Mouth parts of a grasshopper.

**Breathing Organs.** — Observation of the abdomen of a living grasshopper shows frequent movements of the abdomen. On each side of the abdomen in eight of the segments (in the red-legged grasshopper) are found tiny openings called *spir'acles.* These spiracles open into little tubes called *tracheæ* (trā'kē-ē). The tracheæ divide and subdivide like the branches of a tree, so that all parts of the body cavity are reached by their fine endings. Air is drawn in by the expansion of the abdomen and forced out when it contracts. The blood of an insect does not circulate through a system of closed blood tubes

as in man, but instead it more or less completely fills that part of the body cavity which is not occupied by other organs. By means of the tracheæ, air is brought in contact with the blood, which takes in oxygen and gives off carbon dioxide.

**Muscular Activity.** — Insects have the most powerful muscles of any animals of their size. Relatively, an enormous amount of energy is released during the jumping or flying of a grasshopper. The tracheæ pass directly into the muscles and other tissues so that a supply of oxygen is at hand for the oxidation of tissues and the release of energy.

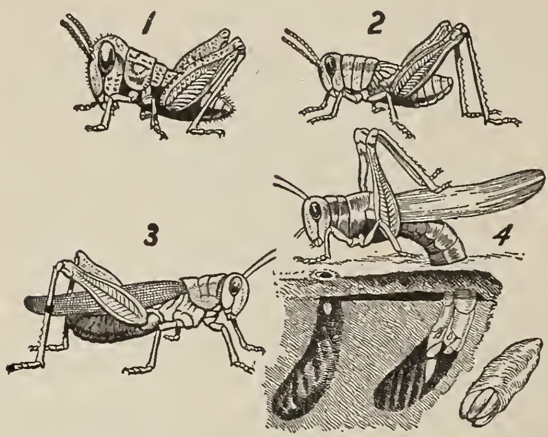
**Food-taking.** — The grasshopper is provided with two pairs of jaws, a forklike ventral-lying pair, the *maxillæ,* and a pair of hard toothed jaws for cutting, called the *man'dibles.* These parts are covered when not in use by two flaps, the upper and lower lips. The leaf upon which the grasshopper feeds is held in place in the mouth by means of the little jaws, or maxillæ, while it is cut into small pieces by the mandibles.

**Blood-making.** — Just behind the mouth is a large crop into which empty the contents of the salivary glands. It is this fluid mixed with digested food that we call the "grasshopper's molasses." After the food is digested by the action of the saliva and other juices, it passes in a fluid state through the walls of the intestine, where it becomes part of the blood. As blood it is passed on to tissues, such as muscle, to make new material to be used in repairing that which is used up during the flight of the insect or to be oxidized to release energy.

**Eyes.** — Examination of the compound eye with a lens shows the whole surface to be composed of tiny hexagonal spaces called *facets* (făs'ĕts). Each facet marks the surface of a unit (*ommatid'ium*) of the compound eye. The separate units of the compound eye probably each give a separate impression of light and color. Thus a compound eye is most favorable for perceiving the movement of objects. The grasshopper has three simple eyes also on the front of the head. The simple eyes probably are able only to perceive light and darkness.

**Other Sense Organs.** — The segmented feelers, or *antennæ,* have to do with the sense of touch and smell. The eardrum, or *tym'panum,* of the grasshopper is found under the wing on the

first segment of the abdomen. Covering the body and on the appendages, are found hairs (sensory hairs) which appear to make the insect sensitive to touch. Thus the armor-covered animal is in touch with its surroundings.



Stages in the life history of the grasshopper. Note the absence of wings in *1* and *2*. The adult female *4* is laying eggs in holes she has made in the ground.

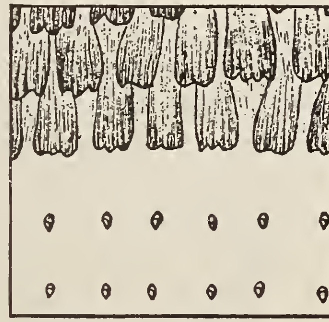
**Nervous System.** — The nerve chain, as in the crayfish, is on the ventral side of the body. It passes around the gullet near the head to the dorsal side, where a collection of ganglia forms the brain. Nerves leave the central system as outgoing fibers which bear *motor* impulses. Other nerve fibers pass inward, and produce sensations. These are called *sensory* fibers.

**Life History.** — The female grasshopper lays her eggs in a hole which she has dug in the ground with her ovipositor. From twenty to thirty fertilized eggs are laid in the fall; these hatch out in the spring as tiny wingless grasshoppers. The young molt in order to grow larger, each grasshopper undergoing about five molts before reaching the adult state. Since no great change in form occurs, the *metamorphosis* is said to be *incomplete.* In the fall most of the adults die, only a few surviving the winter.

**Economic Importance.** — Grasshoppers or locusts have done great harm since the days of the Pharaohs at least. They eat the young leaves of grass, corn, wheat, and other crops, destroying promising fields of grain and sometimes leaving desolate and barren wastes behind them. Birds and parasites are their natural enemies. Plowing the fields after the eggs are laid helps to destroy them.

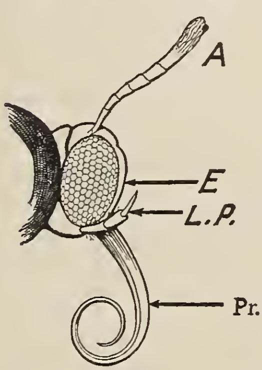
**Relatives of the Locust.** — Among the near relatives are the brown or black crickets, cockroaches and "waterbugs," the katydid, praying mantis, and many others. All of these in-

sects have the hind wings, when present, folded up lengthwise against the body when at rest mouth parts fitted for biting, and an incomplete metamorphosis. They are placed in an order called *Orthop'tera* because the posterior wings are folded straight against the sides of the body when at rest (*orthos*, straight, *pteron*, wing).



Scales and scale sockets on a butterfly's wing.

**The Butterfly.** — The body of the butterfly, as that of the grasshopper, is composed of three regions. The legs of the butterfly are relatively smaller and weaker than those of the grasshopper, while the wings are relatively larger in the first-named insect. Under the microscope the wing is seen to be covered with thousands of little colored scales, each of which fits into a socket in the membranous wing. These scales cause the name *Lepidop'tera* (*lepis*, scale, *pteron*, wing) to be given to this order of insects. The long *proboscis*, a sucking tube through which the insect sucks nectar from the flowers, is another characteristic by which the *Lepidoptera* may be known.




A butterfly's head: *A*, antenna; *E*, compound eye; *L.P.*, labial palpus; *Pr.*, proboscis.

**Life History of the Cabbage Butterfly.** — Although a frequent visitor of our gardens, the cabbage butterfly is perhaps less familiar than the earlier stage in which it appears as a long green worm which eats the cabbage leaves.

*Egg.* — The eggs are laid in the early spring on the leaves of young cabbage plants. They are small, pale yellow, and delicately marked with fine lines. You have to look carefully to find them.

*Larva.* — In about a week the egg hatches and a tiny green worm or *larva* crawls out. It has a long segmented body, three pairs of small true legs on the first three segments of the body, and five pairs of *prolegs* or caterpillar legs farther back, which are of great assistance in holding on to a leaf. The mouth is

provided with toothed mandibles for cutting the leaves. The larva eats ravenously and grows rapidly.

*Pupa.* — After two weeks of active life, the *pupa*, a resting stage, is formed. The larva fastens itself to a cabbage leaf, fence rail, or some other convenient object, and molts. As the skin slips off, the pupa — in this case called a *chrysalis* (krĭs′a-lĭs) — appears. It is a small oval object, usually green, but sometimes varying a little to harmonize with its surroundings. This stage remains for two weeks in summer and longer in cold weather. It then cracks open down the back and the butterfly comes out.

Life history of the cabbage butterfly: *A* adult; *B*, two views of egg, much magnified; *C*, larva; *D*, chrysalis.

*Adult.* — The butterfly has two pairs of large, strong, white or pale yellow wings with two or three black spots on them. The legs are short and weak, the antennæ are slender and knobbed, and the sucking proboscis is coiled like a tiny watch spring on the ventral side of the head.

*A Complete Metamorphosis* is shown by this insect, which during its development passes through four distinct stages — the egg, larva, pupa, and adult.

*Economic Importance and Control.* — The harm is done by the larva, which riddles the cabbage leaves by means of its sharp, pointed mandibles. Spray the plants with a solution of arsenate of lead or Paris green as soon as the larvæ are seen.

**The Moth.** — The big electric-light moth, cecropia, is an insect familiar to most of us. In general it resembles a butterfly in structure. Several differences, however, occur. The body is much stouter than that of a butterfly. The wings and body appear to have a thicker coating of hairs and scales, and the antennæ are feathery. The position of the wings

when at rest forms another easy way of distinguishing the one insect from the other; the butterfly's wings are then held vertical, while a moth's are spread out horizontally or are folded over the body.

**Development.** *The Egg.* — The eggs, cream-colored and as large as a pinhead, are deposited in small clusters on the under side of leaves of the food plant.

*The Larvæ* are at first tiny black caterpillars, which later change to a bluish green color with projections of blue, yellow, and red along the dorsal side.

*The Pupal Stage.* — Unlike the butterfly, the moth passes the quiescent stage in a case which the larva has spun, called a *cocoon.* The cocoon of the cecropia may be found in the fall on willows or alders.

If the cocoon is cut open lengthwise (see Figure), the dormant insect or pupa will be found together with the cast-off skin of the caterpillar which spun the case.

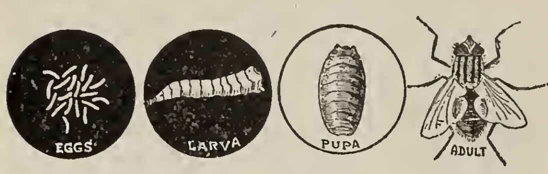
Life history of the cecropia moth. Above, the adult; the larva (caterpillar) in center; the pupal case to right, below; the same cut open at left, below. From photograph loaned by the American Museum of Natural History.

**Silkworms.** — The American silkworm is another well-known moth. The cocoons, made in part out of the leaves of the elm, oak, or maple, fall to the ground when the leaves drop, and hence are not so easily found as those of the cecropia. This moth is a near relative of the Chinese silkworm, and its silk might be used with success were it not for the high rate of labor in this country. The Chinese silkworm (p. 4) is raised with ease in southern California. China, Japan, Italy, and France, because of cheap labor, are still the most successful silk-raising countries.

### Differences Between Moths and Butterflies

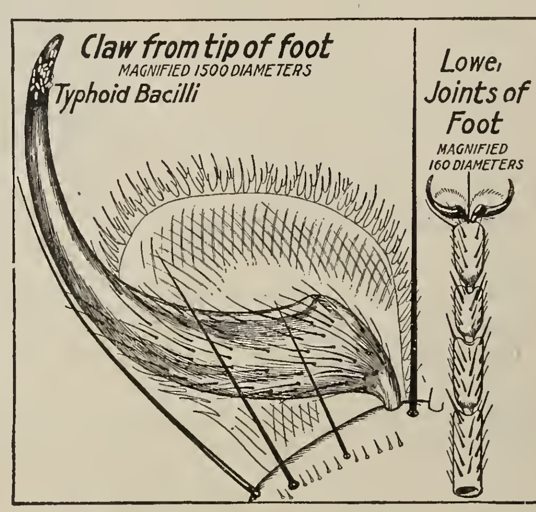
| Butterfly | Moth |
|---|---|
| Antennæ threadlike, usually knobbed at tip. | Antennæ feathery or threadlike, never knobbed. |
| Fly in daytime. | Usually fly at night. |
| Wings held vertically when at rest. | Wings held horizontally or folded over the body when at rest. |
| Pupa naked. | Pupa usually covered by a cocoon. |

Moths and butterflies are both characterized by having a sucking proboscis, membranous wings covered with scales, and by undergoing a *complete* metamorphosis or change of form. By these characteristics we know them to be members of the order *Lepidoptera.*



Complete metamorphosis of the house fly: the four stages in its life history.

**Diptera. The Typhoid Fly.** — This name was given to the common house fly by L. O. Howard, the Chief of the Bureau of Entomology, United States Department of Agriculture; we shall see later with what reason. The body of the fly, as of other insects, has three divisions. The membranous wings appear to be two in number, a second pair being reduced to tiny knobbed hairs called *balancers.* The function of the balancers is apparently that of equilibrium.



Foot of a house fly, highly magnified

*Head.* — The head is freely movable, and the compound eyes are extremely large. Seemingly the fly has fairly acute vision. Home experiments can be easily made which prove its keenness of scent and taste. It is well equipped to care for itself in its artificial environment in the house.

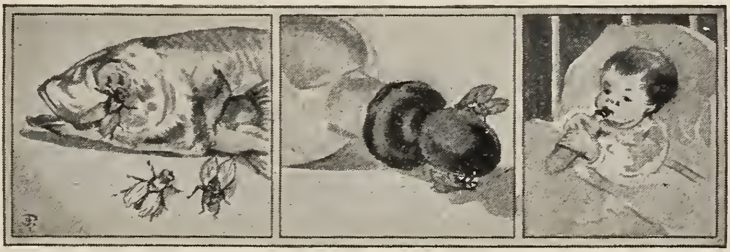
*Mouth Parts.* — The mouth parts of the fly are prolonged to form a proboscis, which is tonguelike, the animal obtaining its food by lapping and sucking. It is the rubbing of this file-like organ over the surface of the skin that causes the painful bite of the horsefly.

*Foot.* — If possible, we should examine the foot of a fly under the compound microscope. The foot shows a wonderful adaptation for clinging to smooth surfaces. Two or three pads, each of which bears tubelike hairs that secrete a sticky fluid, are found

on its under surface. It is by this means that the fly is able to walk upside down. Hooks are also present which doubtless aid in locomotion in this position.

**Development.** — The development of the typhoid fly is extremely rapid. A female may lay from one hundred to two hundred eggs. These are usually deposited in filth or manure. Dung heaps about stables, ash heaps, garbage cans, and fermenting vegetable refuse form the best breeding places for flies. In warm weather, within a day after the eggs are laid, the young maggots, as the larvæ are called, hatch. After about one week of active feeding, these wormlike maggots become quiet and go into the pupal stage, whence under favorable conditions they emerge within less than another week as adult flies. The adults breed at once, and in a short summer there may be over ten generations of flies. This accounts for the great number. Fortunately few flies survive the winter.

Showing how flies may spread disease by means of contaminating food.



When flies are plentiful, there is a considerable increase in the number of cases of illness among babies.

**The Typhoid Fly a Pest.** — The common fly is recognized as a pest the world over. Flies have long been known to spoil food through their filthy habits, but it is more recently that the very

serious charge of spreading diseases, caused by bacteria, has been laid at their door. The foot of the fly, covered with hair and a sticky fluid, is adapted to carry a great many bacteria. In a recent experiment it was found that a single fly might carry anywhere from 500 to 6,600,000 bacteria, the average number being over 1,200,000. Not all of these are harmful, but they might easily include those of typhoid fever, tuberculosis, summer complaint, and possibly other diseases. The rapid increase of flies during the summer months has a definite relation to the increase in the number of cases of summer complaint and probably also of typhoid. It has been estimated that the loss caused from typhoid is in a single year $350,000,000 in the United States alone. A large part of this loss is indirectly due to the typhoid fly.

**Control.** — All windows should be screened during the summer months and food kept away from flies. Flies should be caught in traps or on sticky fly paper. In order to destroy breeding places, all manure and refuse should be removed at least once a week.

**Other Diptera.** — Other examples of the *Dip'tera* group are the mosquitoes, of which more will be said hereafter; the Hessian fly, the larvæ of which feed on young wheat; the botfly, which in a larval state is a parasite in horses; the dreaded tsetse fly of South Africa, which causes disease in horses and cattle by means of the transference of a parasitic protozoan, much like that which causes malaria in man; and many others.

Among the few flies useful to man may be mentioned the tachina flies, the larvæ of which feed on the cutworm, the army worm, and various other kinds of injurious caterpillars.

**Characteristics of Diptera.** — Members of this group have only one pair of wings; the mouth parts are fitted for sucking, rasping, or piercing, and they pass through a complete metamorphosis.

**Coleop'tera: Beetles.** — Beetles are the most widely distributed and among the most numerous of all insects. There are over one hundred thousand living species.

Any beetle will show the following characteristics: (1) The body is usually heavy and broad. Its exoskeleton is hard and tough, this chitinous body covering being better developed in the beetles than in any other of

the insects. (2) The three pairs of legs are stout and rather short. (3) The outer wings are hard and fit over the under wings like a shield. (4) The mouth parts, provided with an upper and lower lip, are fitted for biting. They consist of very heavy curved pincher-shaped mandibles, which are provided with palps.

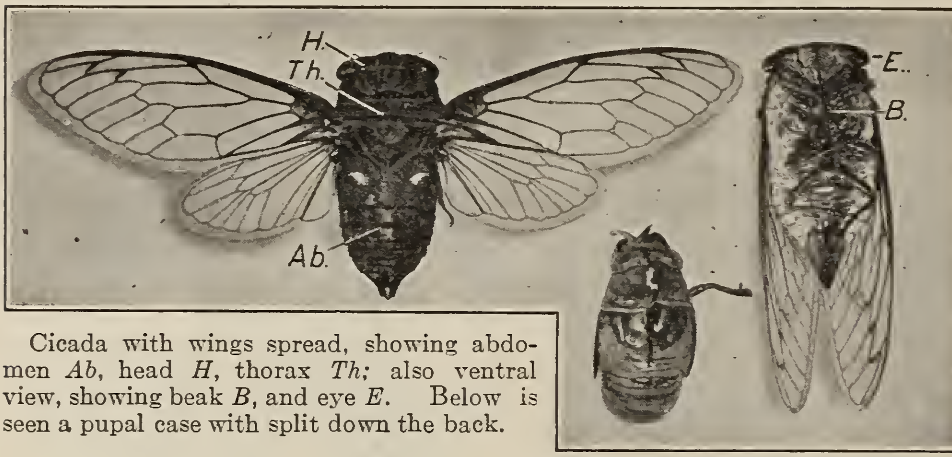
**The Life History of a Beetle.** — The June beetle (May beetle) and potato beetle are excellent examples. May beetles lay their eggs in the ground, where they hatch into cream-colored grubs. A grub differs from the maggot or larva of the fly in possessing three pairs of legs. These grubs live in burrows in the ground, where they feed on the roots of grass and garden plants. The larval form remains underground from two to three years, the latter part of this time as an inactive pupa. During the latter stage it lies dormant in an ovoid area excavated by it. Eventually the wings (which are budlike in the pupa) grow larger, and the adult beetle emerges fitted for its life in the open air.

The potato beetle: eggs, larvæ, pupa, and adults.

**Order Hemip′tera: Bugs.** — The cicada, or, as it is incorrectly called, the locust, is a familiar insect to all. Its droning song, one of the accompaniments of a hot day, is produced by a drumlike organ which can be found just behind the last pair of legs. The sound is caused by a rapid vibration of the tightly stretched drumhead. The body is heavy and bulky. The wings, four in number, are relatively small, but the powerful muscles give them very rapid movement. The anterior wings are larger than the posterior. The legs are not large or strong, the movement when crawling being sluggish. One of the characteristics of the cicada, and of all other bugs, is that the mouth parts are prolonged into a beak with which the animal first makes a hole and then sucks up the juices of the plants on which it lives.

**Life History.** — The seventeen-year cicada lays her eggs in twigs of trees, and in doing this causes the death of the twig. The young leave the tree immediately after hatching, burrow underground, and pass from

thirteen to seventeen years there, depending upon the species of cicada. They live by sucking the juices from roots. During this stage they somewhat resemble the grub of the beetle (June bug) in habits and appearance. When they are about to molt into an adult, they climb above ground, cling to the bark of trees, and then crawl out of the skin as adults.



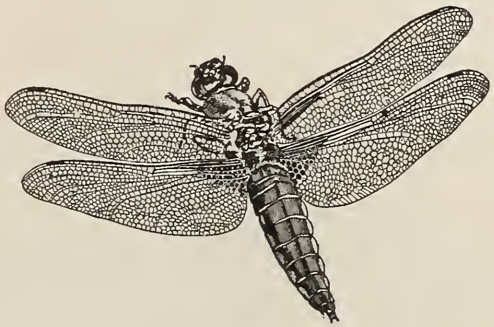

Cicada with wings spread, showing abdomen *Ab*, head *H*, thorax *Th;* also ventral view, showing beak *B*, and eye *E*. Below is seen a pupal case with split down the back.

**Aphids.** — The aphids are among the most interesting of the bugs. They are familiar to all as tiny green lice seen swarming on the stems and leaves of the rose and other cultivated plants. They suck the juices from stem and leaf. Plant lice have a remarkable life history. Early in the year eggs develop into wingless females, which produce living young, all females. These in turn reproduce in a similar manner, until the plant on which they live becomes overcrowded and the food supply runs short. Then a generation of winged aphids is produced. These fly away to other plants, and reproduction goes on as before until the approach of cold weather, when males and females appear. Fertilized eggs are then produced which give rise to young the following season.

The aphids exude from the surface of the body a sweet fluid called honeydew. This is given off in such abundance that it is estimated if an aphid were the size of a cow, it would give two thousand quarts a day. This honeydew is greatly esteemed by other insects, especially the ants. For the purpose of obtaining it, some ants care for the aphids, even providing food and shelter for them. In return the aphid, stimulated by a stroking movement of the antenna of the ant, gives up the honeydew to its protector. (See Figure, page 241.)

**Neurop′tera.** — The dragon fly receives its name because it preys on insects. It eats, when an adult, mosquitoes and other insects which it captures while on the wing. Its four large lacelike wings give it power of very rapid flight, while its long narrow body is admirably adapted for the same purpose. The large compound eyes placed at the sides of the head give keen sight. It possesses powerful jaws (almost covered by the upper and lower lips).

The long, thin abdomen does not contain a sting, contrary to the belief of most children. These insects deposit their eggs in the water, and the fact that they may be often seen with the end of the abdomen curved down under the surface of the water in the act of depositing the eggs has given rise to the belief that they were then engaged in stinging something. The egg hatches into a form of larva called a *nymph*, which in the dragon fly is characterized by a greatly developed lower lip. When the animal is at rest, the lower lip covers the large biting jaws, which can be extended so as to grasp and hold its prey. The nymphs of the dragon fly take oxygen out of the water by means of gill-like structures placed in the posterior part of the food tube. They may live as larvæ from one summer to as long as two years in the water. They then crawl out on a stick, molt by splitting the skin down the back, and come out as adults.



Dragon fly: notice the long abdomen and large compound eyes.

A nearly related form is the damsel fly. This may be distinguished from the dragon fly by the fact that when at rest the wings are carried close to the abdomen, while in the dragon fly they are held in a horizontal position.

**May Flies.** — Another near relative of the dragon fly is the May fly. These insects in the adult stage have lost the power to take food. Most of their life is passed in the larval stage in the water. The adults sometimes live only a few hours, just long enough to mate and deposit their eggs.

**Hymenop'tera.** — We have already learned something of the structure of the bee, an example of this order. Other relatives are the wasps, ichneumons (wasp-like insects with long ovipositors), and the ants. The structural characteristics of this group are two pairs of membranous wings, and mouth parts fitted for biting and lapping. They all undergo a complete metamorphosis, the young being helpless wingless creatures somewhat like the maggots of the fly. Of this group we shall learn more later.

**Characteristics of Insects.** — The orders of insects mentioned above are only a few examples of this very large group. In all of the above forms we have seen certain likenesses and certain differences in structure, but all of the above have had three body divisions, three pairs of legs, and have possessed in the adult stage air tubes called tracheæ. These are the principal characteristics by which we may identify the insects.

**Spiders and Myriapods.** — Spiders, millepedes, and centipedes are not true insects, although they are nearly allied to them.

The body of a *spider*, like that of the higher crustaceans, has only two divisions, cephalothorax and abdomen; *four* pairs of walking legs mark another difference from insects. Wings are always lacking. Spiders usually have four pairs of simple eyes and breathe by means of lunglike sacs in the abdomen, the openings of which can sometimes be seen just behind the most posterior pair of legs. Another organ possessed by the spider, which insects do not have (except in a larval form), is known as the *spinneret*. This is a set of glands which secrete in a liquid form the silk which the spider spins. On exposure to air, this fluid hardens and forms a very tough building material which combines lightness with strength.

Tarantula, a spider, about one third actual size. The palpi and the four pairs of legs are attached to the cephalothorax; the spinnerets are at the end of the abdomen, below. Photograph from American Museum of Natural History.

**Uses and Form of the Web.** — The web-making instinct of spiders forms an interesting study. Our common spiders may be grouped according to the kind of web they spin. The web in some cases is used as a home; in others it forms a snare or trap. Occasionally the web is used for ballooning, spiders having been noticed clinging to their webs miles out at sea. The webs seen most frequently are the so-called cobwebs. These usually serve as a snare rather than a home, some species remaining away from the web most of the time. Other webs are funnel-shaped, still others are of geometrical exactness, while one form of spider makes its home underground, lines the hole with silk, and makes a trapdoor which can be closed after the spider has retreated to its lair.

**Myriapods.** — We are all familiar with the harmless and common thousand legs found under stones and logs. It is a representative of the group of animals known as the millepedes. These animals have the body divided into two regions, head and trunk, and have two pairs of legs for each body segment. The centipedes, on the other hand, have only one pair of legs to each segment. Both are representatives of the class *Myriap'oda*. None of the forms in the eastern part of the United States are poisonous.

**Insects and Crustaceans Compared.** — Both crustaceans and insects belong to a large group of animals which agree in that they have jointed appendages and bodies, and that they possess an exoskeleton. This group or phylum is known as the *Arthrop'oda.* Spiders and myriapods are also included in this group.

Insects differ structurally from crustaceans in having three regions in the body instead of two. The number of legs (three pairs) is definite in the insects; in the crustaceans the number

A poisonous centipede from Texas. Half natural size. From photograph by Davison.

sometimes varies, but is always more than three pairs. The exoskeleton, composed wholly of chitin in the insects, is usually strengthened with lime in the crustaceans. Both groups have compound eyes, but those of the Crustacea are stalked and movable. The other sense organs do not differ greatly. The most marked differences are physiological. The crustaceans take in oxygen from the water by means of gills, while the insects are air breathers, using for this purpose air tubes called *tracheæ.*

Both insects and crustaceans, because of their exoskeleton, must molt in order to increase in bulk.

## Classification of Arthropoda

### Phylum Arthropoda

Class, *Crusta'cea.* Arthropods with limy and chitinous exoskeleton, rarely more than 20 body segments, usually breathing by gills, and having two pairs of antennæ.

Subclass I. *Entomos'traca.* Crustacea with a variable number of segments, chiefly small forms with simple appendages. Some degenerate or parasitic. Examples: barnacles, water flea (*Daphnia*), and co'pepod (*Cy'clops*).

Subclass II. *Malacos'traca.* Usually large Crustacea having nineteen pairs of appendages. Examples: American lobster (*Hom'arus americа'nus*), crab (*Cancer*), and shrimp (*Palæmon'etes*).

Class, *Hexap'oda* or *Insecta* (insects). Arthropoda having chitinous exoskeleton, breathing by air tubes (*tracheæ*), and having three distinct body regions.

*Order, Ap'tera* (without wings). Several wingless forms. Example: springtails.

*Order, Orthoptera* (straight wings). Example: Rocky Mountain locust.

*Order, Lepidoptera* (scale wings). Examples: cabbage butterfly, cecropia moth.

*Order, Diptera* (two wings). Examples: fly, mosquito.

*Order, Hemiptera* (half wing). Examples: all true bugs, plant lice, and cicada.

*Order, Neuroptera* (nerve wings). Examples: May fly, dragon fly.

*Order, Coleoptera* (shield wings). Example: beetles.

*Order, Hymenoptera* (membrane wings). Examples: bees, wasps, ants.

Class, *Arachnida* (a-răk'nĭ-da). Arthropoda with head and thorax fused. Six pairs of appendages. No antennæ. Breathing by lung sacs (spiders) or tracheæ. Examples: spiders and scorpions.

Class, *Myriapoda.* Arthropoda having long bodies with many segments; one or two pairs of appendages to each segment. Breathing by means of tracheæ. Example: centipede.

An exercise for field work with a simple key for identification of orders will be found in Sharpe's *Laboratory Manual,* Prob. XXX.

**Summary.** — This chapter has attempted to have you build up your own definition of what an insect is by comparing a number of orders to see what characteristics they have in common. You have found them to have a segmented body, with three divisions, head, thorax, and abdomen, three pairs of jointed legs, a chitinous body covering, compound and usually simple eyes, breathing through air tubes (tracheæ), and undergoing a metamorphosis.

**Problem Questions.** — 1. Give ten good reasons why insects are so numerous.

2. Give briefly the characteristics of the Orthoptera, Lepidoptera, Diptera, Hymenoptera.

3. How do insects and crustaceans differ?
4. Make a table classifying the Arthropoda.

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## XX. GENERAL CONSIDERATIONS FROM THE STUDY OF INSECTS

**Problem.** *To determine how insects have become winners in life's race by means of —*

(*a*) *Protective resemblance.*
(*b*) *Aggressive resemblance.*
(*c*) *Mimicry.*
(*d*) *Communal life.*
(*e*) *Symbiosis.*
(*f*) *Parasitism.*

(*Laboratory Manual, Prob. XXXI; Laboratory Problems, Probs. 14, 15.*)

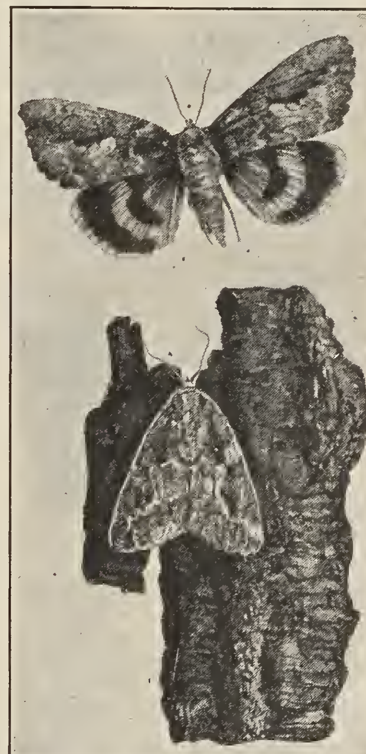
Insects are by far the most numerous of all animals. It is estimated that there are more species of insects than of all other kinds of animals upon the globe. Why should insects have developed in so much greater numbers than other animals? We cannot explain this, but some light is thrown on the problem when we consider some of the ways in which insects have become winners in life's race.


Three walking sticks on a twig, showing protective resemblance.

**Protective Resemblance.** — When we remember that the chief enemies of insects are birds and other animals which use them as food, we can see that the insect's power of rapid flight must have been of considerable importance in escaping from enemies. But other means of protection are seen when we examine insects in their native haunts. We have noted that various animals, such as the earthworm and crayfish, escape observation because they have the color of their

surroundings. Insects give many interesting examples of protective coloration or protective resemblance. The grasshopper is colored like the grass on which it lives. The katydid, with its green body and wings, can scarcely be distinguished from the leaves on which it rests. The walking stick, which resembles the twigs on which it is found, and the walking-leaf insect of the tropics, are other examples.

One example frequently described is the dead-leaf butterfly of India. This insect at rest resembles a dead leaf attached to a limb; in flight it is conspicuous, because of its vivid colors. The underwing moth is another example of a wonderful simulation of the background of bark on which the animal rests in the daytime. At night the brightly colored underwings perhaps give a signal to others of the same species. The beautiful luna moth, in color a delicate green, rests by day among the leaves of the hickory. When frightened, measuring worms stand out stiff upon the branches on which they crawl, thus simulating lateral twigs. Hundreds of other examples might be given.



Underwing moth: above, in flight; below, at rest on bark.

This likeness of an animal to its immediate surroundings has already been noted as *protective resemblance.*

**Aggressive Resemblance.**— Sometimes animals which resemble their surroundings are thus better able to catch their prey; they show *aggresive resemblance.* The polar bear is a notable example. The mantis has strongly built fore legs, with which it seizes and holds insects on which it preys. It has the color of its immediate surroundings, and is thus enabled to seize its prey before the latter is aware of its presence. Many other examples could be given.

**Warning Coloration and Protective Mimicry.**— Some insects are

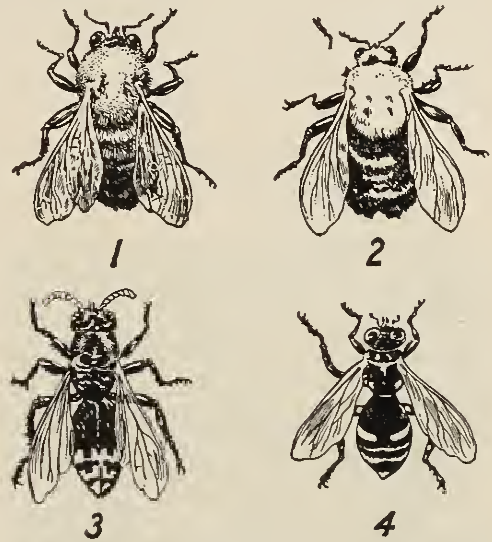
extremely unpleasant, either to smell or to taste, while others are provided with means of defense such as poison hairs or stings. Those animals which are harmful and brightly colored or marked as if to warn animals to keep off or to take the consequences, show *warning coloration*. Examples of insects which show warning by color may be seen in many examples of beetles, especially the spotted ladybirds, potato beetles, and the like. Wasps show yellow bands, while many forms of caterpillars are conspicuously marked or colored.

Monarch and viceroy butterflies: the viceroy (below) shows protective mimicry.

Some insects, especially caterpillars, which are harmless, are brightly colored and protrude horns, or pretend to sting when threatened with attack. These animals evidently mimic animals which really are protected by a sting or by poison, although this is not voluntary on the part of the insect. When a harmless insect resembles a harmful insect we call it *mimicry*.

One of the best-known examples of insect mimicry is seen in the imitation of the monarch butterfly by the viceroy. The monarch butterfly (*Anosia plexippus*) is an example of a race which has received protection from enemies in the struggle for life, because of its nauseous taste, and, perhaps, because its caterpillar feeds on plants of no commercial value. Another butterfly, less favored by nature, resembles the monarch in outward appearance. This is the viceroy. It seems probable that in the early history of this edible species some of them escaped from the birds because they resembled in both color and form the species of inedible monarchs. So for generation after generation the ones which were most like the inedible species lived and produced new offspring, the others becoming the food of birds. Ultimately a species of butterflies was formed that owed its

existence to the fact that it resembled another more favored species. This is one of the ways in which nature selects the animals which exist upon the earth. Many other examples of mimicry may be found among insects. Some harmless flies imitate bees, which sting, as shown in the figure.



Supposed cases of mimicry: 1, a bumblebee, mimicked by 2, a kind of fly; 3, a wasp, mimicked by 4, another kind of fly. The bumblebee and wasp are of the order Hymenoptera; the mimics, of the order Diptera.

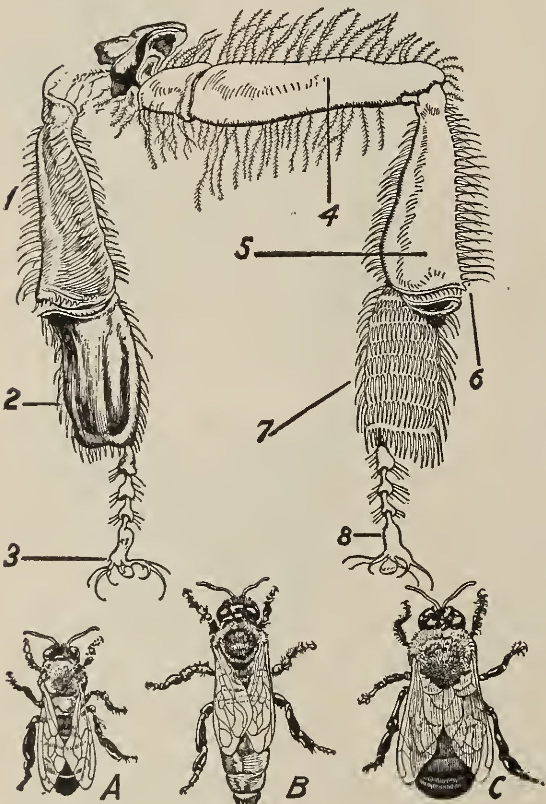
**Other means of Protection.** — The chief insect enemies are the birds, and from these the most effective protection seems to be hairs on the body. Few birds eat hairy caterpillars of any species; fortunately, however, the hairy larvæ of the gypsy moth, a serious pest, are eaten by no less than thirty-one species of birds. The odors or ill flavors of insects seem to be generally protective, but stinging insects do not appear to be protected from all birds, flycatchers and swallows habitually feeding on the bees and wasps. There is a growing tendency among zoölogists to place less emphasis on these adaptations as a means of preserving species.

**Communal Life among Insects.** — Insects are of special interest to man because among certain species a system of social life has arisen comparable to that which exists among men. In connection with this communal life, nature has worked out a division of labor which is very remarkable. This can be seen in tracing out the lives of several of the insects which live in communities.

**Solitary Wasps.** — Some bees and wasps lead a solitary existence. The solitary and digger wasps do not live in communities. Each female constructs a burrow in which she lays eggs and rears her young. The young are fed upon spiders and insects previously caught and then stung into insensibility. The nest is closed up after food is supplied, and the

young later gnaw their way out. In the life history of such an insect there is no communal life.

**Bumblebee.** — In the life history of the big bumblebee we see the beginning of the community instinct. Some of the female bees (known as *queens*) survive the winter and lay their eggs the following spring in a mass of pollen, which they have previously gathered and placed in a hole in the ground. The young hatch as larvæ, then pupate, and finally become workers, or imperfect females in which the egg-laying apparatus, or ovipositor, is modified to be used as a sting. The workers bring in pollen to the queen, in which she lays more eggs. Several broods of workers are thus hatched during a summer. In the early fall a brood of males or drones, and egg-laying females or queens, are produced instead of workers. By means of these egg-producing females the brood is started the following year.




The honeybee: *A*, worker; *B*, queen; *C*, male (drone). Above is shown a worker's hind leg, as seen from the side and from behind: 4, femur; 1, 5, tibia; 2, 7, metatarsus; 3, 8, foot; 6, wax shears.

**The Honeybee.** — The most wonderful communal life has been developed among the honeybees.[1]

The honeybee in a wild state makes its home in a hollow tree; hence the term "bee tree." In the hive the colony usually consists of a queen, or egg-laying female, a few hundred drones, or males, and several thousand imperfect females, or

[1] Their daily life may be easily watched in the schoolroom, by means of one of the many good and cheap observation hives now made to be placed in a window frame. Directions for making a small observation hive for school work can be found in Hodge, *Nature Study and Life*, Chapter XIV. Bulletin No. 1, U.S. Department of Agriculture, entitled *The Honey Bee*, by Frank Benton, is valuable for the amateur beekeeper. Farmers' Bulletin 447 on *Bees*, by E. F. Phillips, is also most useful.

workers. The colonies vary greatly in numbers, in a wild state there being fewer in the colony. The division of labor is well seen in a hive in which the bees have been living for some weeks. The queen does nothing except lay eggs, sometimes laying three thousand eggs a day and keeping this up, during the warm weather, for several years. She may lay a million eggs during her life. She does not, as is popularly believed, rule the hive, but is on the contrary a captive most of her life. Most of the eggs are fertilized by the sperm cells of a male; the unfertilized eggs develop into males or drones. After a short existence in the hive the drones are usually driven out by the workers. The fertilized eggs may develop into workers, but if the young larva is fed with a certain kind of food, it will develop into a young queen.

Hornets' nest, open to show the cells of the comb. Photograph by Overton.

The cells of the comb are built by the workers out of wax secreted from the under surface of their bodies. The wax is cut off in thin plates by means of the wax shears between the two last joints of the hind legs. These cells are used by the queen to place her eggs in, one to each cell, and the young are hatched after three days, to begin life as footless white grubs. For a few days they are fed on partly digested food called bee jelly, regurgitated from the stomach of the workers. Later they receive pollen and honey to eat. A little of this mixture, known as bee bread, is put into the cells, and the lids covered with wax by the working bees, and the young larvæ allowed to pupate. After about two weeks of quiescence in the pupal state, the adult worker breaks out of the cell and takes her place in the hive, first caring for the young

as a nurse, later making excursions to the open air after food as an adult worker.

If a new queen is to be produced, several of the cell walls are broken down by the workers, making a large ovoid cell in which one egg is left. The young bee in this cell is fed during its whole larval life upon bee jelly, and grows into a queen of much larger size than an ordinary worker. When a young queen appears, great excitement pervades the community; the bees appear to take sides; some remain with the young queen in the hive, while others follow the old queen out into the world. This is called swarming. They usually settle around the queen, often hanging to the limb of a tree. While the bees are swarming, certain of the workers, acting as scouts, determine on a site for their new home; and, if undisturbed, the bees soon go there and construct their new hive. This instinct is of vital importance to the bees, as it provides them with a means of forming a new colony. A swarm of domesticated bees may be quickly hived in new quarters.

We have already seen (pages 31 and 32) that the honeybee gathers nectar; this is swallowed and kept in the crop until after the return to the hive, where it is regurgitated into cells of the comb. It is now thinner than what we call honey. To thicken it, the bees swarm over the open cells, moving their wings very rapidly, thus evaporating some of the water in the honey. A hive of bees has been known to make over thirty-one pounds of honey in a single day, although the average record is very much less than this.

**Ants.** — Ants are the most truly communal of all the insects. Their life history and habits are not so well known as those of the bee, but what is known shows even more wonderful specialization. The inhabitants of a nest may consist of wingless workers, which in some cases may be of two kinds, and winged males and females.

Ant larvæ are called grubs. They are absolutely helpless and are taken care of by nurses. The pupæ may often be seen as they are taken out in the mouths of the nurse ants for sun and air. They are wrongly called ants' eggs in this stage.

The nest of a colony consists of underground galleries with enlarged storerooms, nurseries, etc. The ants are especially fond of honeydew secreted by the aphids, or plant lice. Some species of ants provide elaborate stables

for the aphids, commonly called ants' cows, supplying them with food and shelter and taking the honeydew as their reward. This they obtain by licking it from the bodies of the aphids. A Western form of ant, found in New Mexico and Arizona, rears a scale insect on the roots of the cactus for the same purpose.

It is probable that some species of ants are among the most warlike of any insects. In the case of the robber ants, which live entirely by war and pillage, the workers have become modified in structure, and can no longer work, but only fight. Some species go further and make slaves of the ants preyed upon. These slaves do all the work for their captors, even to making additions to their nest and acting as nurses to their young.

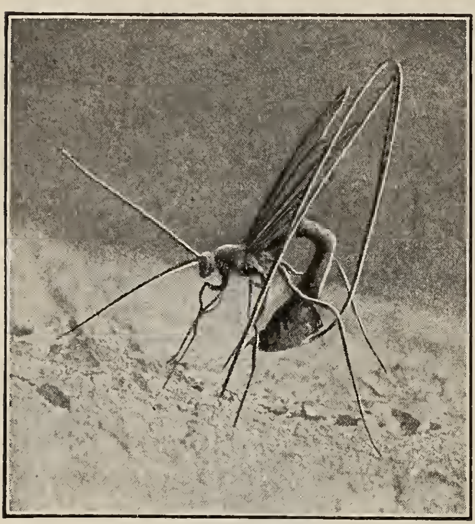

Ants and their "cows" (aphids).

The entire communal life of the ants seems to be based upon the perception of odor. If an ant be put into a colony to which it does not belong, although one of the same species, it will be set upon and either driven out or killed. Ants never really lose their community odor; those absent for a long time, on returning, will be easily distinguished by their odor, and eagerly welcomed by the members of the nest. The communication of ants as seen when they stop each other, away from the nest, is evidently a process of smelling, for they caress each other with the antennæ, the organs with which odors are perceived.

**Symbiosis.** — We have already seen that plants and animals frequently live in a state of partnership or relation of mutual help. Such a state is known as a *symbiotic* relation. The keeping of the aphids by the ants which use them as "cows" is an example of this relation among two species of insects. The ants provide protection and sometimes food; the aphids give up the honeydew of which the ants are so fond.

But a wider symbiotic relation exists directly between the flowering plants and the insects. We all know the very great service done the plants by the pollination of the flowers by the insects, and we know that the return is the supply of pollen and nectar as food for the insects.

**Parasitism.** — One of the near relatives of the bee called the ichneumon (ĭk-nū′mon) fly does man indirectly considerable good because of its habit of laying its eggs and leaving its young to develop in the bodies of caterpillars which are harmful to vegetation. As this is death for the caterpillar, it is safe to say that by the above means the ichneumons save millions of dollars yearly to this country.



Ichneumon fly (Thalessa) boring in an ash tree to deposit its eggs in the burrow of a horntail larva, a wood borer. From photograph, natural size by Davison.

Unfortunately, not all insect parasites do good. Animals of all kinds, but especially birds, are infested with lice and fleas. The ticks are well known for the harm they do, while the larvæ of the botflies which live in the bodies of various mammals, as the horse and sheep and cattle, are insect parasites which do much harm.

***Problem.*** *Some relations of insects to man.* (*Laboratory Manual, Prob. XXXII; Laboratory Problems, Probs. 123* to *131.*)

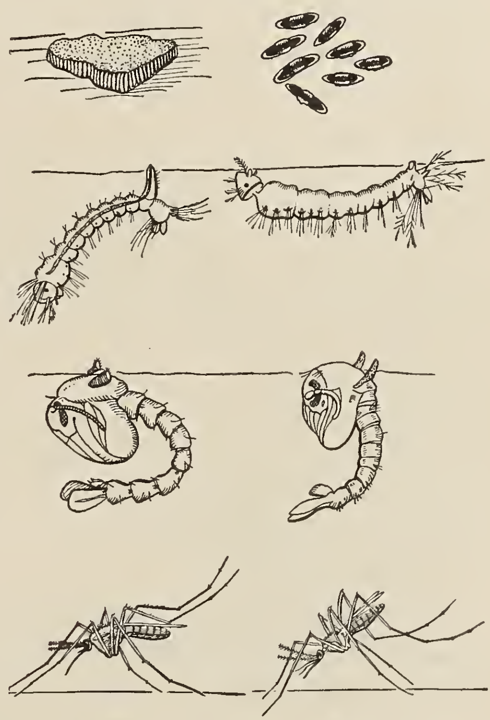
(*a*) *With reference to disease.*

(*b*) *With reference to destruction of property.*

(*c*) *With reference to benefit to man.*

**The Relation of Insects to Mankind.** — We already have seen this relation is twofold, harmful and beneficial. The harmful relation may affect man directly, as when human disease is carried by insects, or it may be indirect, as in the case of damage to crops, trees, stored food, or clothing. The first relation is naturally of more importance, as malaria, an extremely prevalent disease in some parts of the world, is carried by mosquitoes, and typhoid and other intestinal diseases are often distributed by flies.

**The Malarial Mosquito.** — Fortunately for mankind, not all mosquitoes harbor the small one-celled parasite (a protozoan) which causes malaria. The harmless mosquito (*culex*) may be usually distinguished from the mosquito (*anopheles*) which carries malaria by the position of the body and legs when at rest. (See Figure.) Culex lays eggs in tiny masses shaped like rafts of one hundred or more eggs in standing water; thus the eggs are distinguished from those of anopheles, which are not in rafts. In a short time enough mosquitoes to stock a neighborhood may develop in rain barrels, gutters, or old cans. The larvæ are known as wigglers. They appear to hang on the surface of the water, head down in order to breathe through a tube at the posterior end of the body, the end of which projects a short distance above the water. In this stage they may be easily recognized by their peculiar movement when on their way to the surface to breathe. The fact that both larvæ and pupæ take air from the surface of the water makes it possible to kill the mosquitoes during these stages by pouring oil on the surface of the water where they breed. The introduction of minnows, goldfish, or other small fish which feed upon the larvæ in the water where the mosquitoes breed will do much in freeing a neighborhood from this pest. Draining swamps or low lands which hold water after a rain is another method of extermination.



Life history of two mosquitoes — at the left, culex; at the right, anopheles. Note the four steps of each — eggs, larva, pupa, adult.

Since the beginning of historical times, malaria has been prevalent in regions infested by mosquitoes. The ancient city

of Rome was so greatly troubled by periodic outbreaks of malarial fever that a goddess of fever was worshiped in order to lessen the severity of what the inhabitants believed to be a divine visitation. As recently as 1900 two doctors lived in the most malarious district in the swampy area near Rome, drank the water and lived the same life as did the natives; only taking the precaution to screen themselves from the *anopheles* mosquito. They remained free from malaria. A little later came the proof that malaria was carried by anopheles. Living mosquitoes which had bitten malarial patients were shipped to England, and there two English doctors allowed these mosquitoes to bite them. They came down with malaria. These experiments and others have shown the world how to combat malaria successfully.

**Yellow Fever and Mosquitoes.** — Another disease which has been proved to be carried by mosquitoes is yellow fever. In the year 1878 there were 125,000 cases and 12,000 deaths in the United States, mostly in Alabama, Louisiana, and Mississippi. During the French occupation of the Panama Canal zone the work was at a standstill part of the time because of the ravages of yellow fever.

But to-day this is changed, and thanks to the experiments performed in Cuba in 1900 by the commission headed by Major Walter Reed, yellow fever is under almost complete control, both here and wherever the mosquito (*aëdes*, formerly called *stegomyia*) which carries yellow fever exists. During the series of experiments two doctors, Dr. James Carroll and Dr. Jesse W. Lazear, allowed themselves to be bitten by *aëdes* mosquitoes which had previously bitten yellow fever patients. Both had yellow fever and Dr. Lazear died. Later others were similarly experimented upon with the result that we now know conclusively that yellow fever is transmitted only by means of a mosquito. Hence it has been possible, by draining, oiling, and screening, to make Panama a safer place to live in than many parts of the United States.

**Other Diseases due to Insects.** — The bubonic plague, the dreaded scourge of the East, is brought to man by fleas. The sleeping sickness of Africa has already been mentioned (page

179) as carried by the tsetse fly. Several other diseases of man and of many other animals, especially cattle, are carried by flies. The Texas fever of cattle is carried by a cattle tick, an animal closely allied to the insects.

**Economic Loss from Insects.** — The money value of crops, forest trees, stored foods, and other materials destroyed annually by insects is beyond belief. It is estimated that they get one tenth of the country's crops, at the lowest estimate a matter of some $300,000,000 yearly.

"A recent estimate by experts put the yearly loss from forest insect depredations at not less than $100,000,000. The common schools of the country cost in 1902 the sum of $235,000,000, and all higher institutions of learning cost less than $50,000,000, making the total cost of education in the United States considerably less than the farmers lost from insect ravages." — *Slingerland.*

In 1874–1876 the damage to crops by the Rocky Mountain locust has been estimated at $200,000,000. The total value of all farm and forest crops, excluding animal products, in New York, is perhaps $150,000,000, and the one tenth that the insects get is worth $15,000,000. It may seem incredible that it costs such a sum to feed New York's injurious insects every year, but it is an average of $66 for each of the 227,000 farms in the state; and there are few farms where the crops are not lessened more than this amount by insects.

**Insects which damage Garden and Other Crops.** — The grasshoppers have been mentioned as among the most destructive of these. The larvæ of various butterflies and moths do considerable harm, especially the "cabbage worm," the various caterpillars of the hawk moths which feed on grape and tomato vines, the cutworm, a feeder on the roots of all kinds of garden truck, the corn worm, a pest on corn, cotton, tomatoes, peas, and beans. The last damages the cotton crop to the amount of several millions of dollars annually.

Among the beetles which are found in gardens is the potato beetle, which destroys the leaves of the potato plant. This beetle formerly lived in Colorado upon a wild plant of the same family as the potato, and came east upon the introduction of the

potato into Colorado, evidently preferring cultivated forms to wild forms of this family. The asparagus and cucumber beetles are also often in evidence.

The one beetle doing by far the greatest harm in this country is the cotton-boll weevil. Imported from Mexico, since 1892 it has spread over most of the cotton-growing states. The beetle lays its eggs in the young cotton fruit or boll, the larvæ feeding upon the substance within the boll. It is estimated that if unchecked this pest would destroy yearly one half of the cotton crop, a matter of over $300,000,000. Fortunately, the experts of the United States Department of Agriculture are at work on the

Four destructive insects: from left to right, the cotton boll weevil, the potato beetle, the squash bug, and the celery caterpillar.

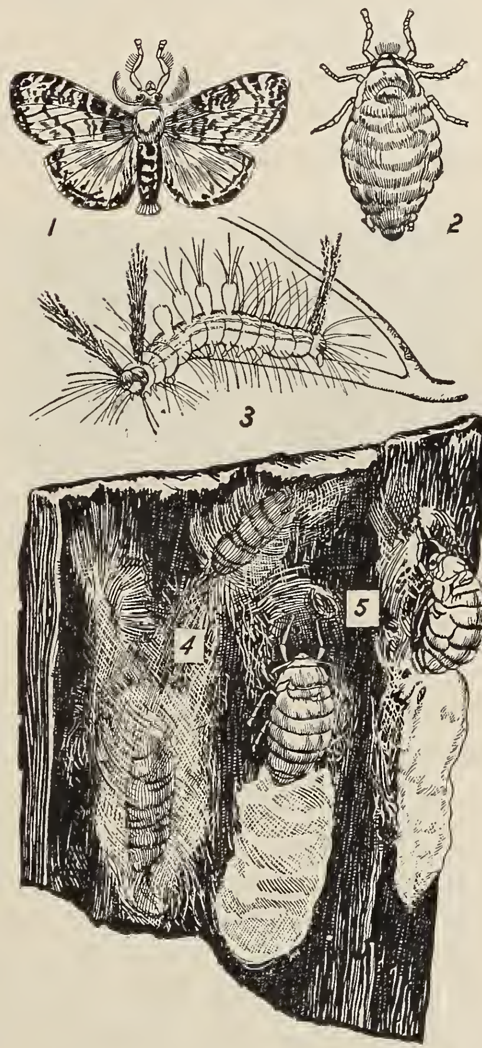
problem, and, while they have not found any way of exterminating the beetle as yet, it has been shown that, by planting more hardy varieties of cotton, the crop matures earlier and ripens before the weevils have increased in sufficient numbers to destroy the crop (see page 51).

The bugs are among our destructive insects. The most familiar examples of our garden pests are the squash bug; the chinch bug, which yearly does damage estimated at $20,000,000, by sucking the juice from the leaves of grain; and the plant lice, or aphids. Some aphids are extremely destructive to vegetation. One, the grape Phylloxe′ra, yearly destroys immense numbers of plants in the vineyards of France, Germany, and California.

The Hessian fly, the larvæ of which live on the wheat plant, was introduced accidentally by the Hessians in their straw

bedding during the Revolution, and has become one of our most serious insect pests.

**Insects which harm Fruit and Forest Trees.** — Great damage is done annually by the larvæ of moths. Massachusetts has already spent over $5,000,000 in trying to exterminate the accidentally imported gypsy moth. The codling moth, which bores into apples and pears, is estimated to ruin yearly $3,000,000 worth of fruit in New York alone, which is only one of the important apple regions of the United States. The codling moth flits over the fruit blossoms and lays an egg here and there — one in a blossom. The young hatch in a day or two and eat their way into the ovary, where they feed and grow with the fruit. The fruit ripens early and often falls to the ground before the perfect fruit is ripe. The larva crawls out and up the tree and pupates in the bark.



Tussock moth: 1, adult male; 2, adult female, which has no wings; 3, larva; 4, pupæ; 5, female laying eggs.

Among these pests, the most important to the dweller in a large city is the tussock moth, which destroys the leaves of the shade trees. The caterpillar may be recognized easily by its long hairs of yellow, brown, and black, and a tuft of red on its head. The cocoon is made of a combination of hairs and silk on the bark of a tree, or on a twig. The female has no wings and cannot crawl far. She lays her eggs, therefore, on

the outside of the cocoon and dies a few hours later. The eggs remain over winter. By collecting and burning the egg masses in the fall, we may save many shade trees the following year.

Other enemies of the shade trees are the fall webworm, the forest caterpillar, and the tent caterpillar; the last spins a tent which serves as a shelter in wet weather.

The larvæ of some moths damage the trees by boring into the wood of the tree on which they live. Such are the peach, apple, and other fruit-tree borers common in our orchards. Some species of beetles produce boring larvæ which eat their way into trees and then feed upon the sap of the tree. Many trees in our Adirondack Forest Reserve annually succumb to these pests because the beetle girdles the tree, cutting through the tubes in the cambium region. Most fallen logs will repay a search for the larvæ which bore between the bark and wood.

San José scale, and a twig covered with the scales.

Among the insects most destructive to trees are the scale insects and the plant lice, or aphids. The San José scale, a native of China, was introduced into the fruit groves of California about 1870 and has spread all over the country. It lives upon numerous plants, and is one of the worst pests this country has seen. It is interesting to know that a ladybird beetle, which has also been imported, is the most effective agent in keeping this pest in check.

**Insects of the House or Storehouse.** — The weevils are the greatest pests, frequently ruining tons of stored corn, wheat, and other cereals. Roaches feed on almost any kind of breadstuffs as well as on clothing. The carpet beetle is a recognized foe of the housekeeper, the larvæ feeding upon all sorts of woolen material. The larvæ of the clothes moth do an immense amount of damage

to stored clothing especially. Fleas, lice, and especially bedbugs are among man's personal foes.[1]

**Beneficial Insects.** — Fortunately for mankind, many insects are found which are of use because they either prey upon injurious insects or become parasites upon them, eventually destroying them. The ichneumon flies are examples already mentioned. They undoubtedly do much in keeping down the number of destructive caterpillars.

Several beetles are of value to man. Most important of these is the natural enemy of the orange-tree scale, the ladybug, or ladybird beetle. In New York state it may often be found feeding upon the plant lice. The caloso′ma beetle preys upon the gypsy moth. The carrion beetles and many water beetles act as scavengers. The sexton beetles bury dead carcasses of animals. Ants in tropical countries are particularly useful as scavengers.

Insects, besides pollinating flowers, often do a service by eating harmful weeds which are thus kept in check. We have noted that insects spin silk, thus forming clothing, that in many cases they are preyed upon, and support an enormous multitude of birds, fish, and other animals with food.

**How the Damage done by Insects is Controlled.** — The combating of insects by the farmer is controlled and directed by two bodies of men, both of which have the same end in view. These are the Bureau of Entomology of the United States Department of Agriculture and the various state experiment stations.

The Bureau of Entomology works in harmony with the other divisions of the Department of Agriculture, giving the time of its experts to the problems of controlling insects which, for good or ill, influence man's welfare in this country. Such problems as the destruction of the malarial mosquito and the control of the typhoid fly; the destruction of harmful insects by the introduction of their natural enemies, plant or animal; the perfecting of the honeybee (see Hodge, *Nature Study and Life*, page 240), and the introduction of new species of insects to pollinate flowers not native to this country (see the fig wasp, page 36), are a few of those to which these men devote their time.

[1] Directions for the treatment of these pests may be found in pamphlets issued by the U.S. Department of Agriculture.

All the states and territories have, since 1888, established state experiment stations, which work in coöperation with the government in the war upon injurious insects. These stations are often connected with colleges, so that young men who are interested in this kind of natural science may have opportunity to learn and to help. Bulletins are published by the various state stations and by the Department of Agriculture, most of which may be obtained free. The most interesting are the Farmers' Bulletins, issued by the Department of Agriculture, and the pamphlets issued by Cornell University in New York state.

## TABLE SHOWING A FEW INSECTS OF ECONOMIC IMPORTANCE AND MEANS FOR THEIR CONTROL OR EXTERMINATION

### 1. Beneficial Insects

*Silk Moth.* — Larva spins a cocoon from which silk is made.

*Honeybee.* — Adult produces honey and pollinates flowers.

*Bumblebee.* — Adult pollinates red clover and fruit trees.

*Ichneumon Fly.* — Female lays eggs in the bodies of harmful larvæ (as the grapevine caterpillar and the tree borers). The developing parasites feed on the hosts and kill them.

*Dragon Fly.* — Adult feeds on mosquitoes.

*Ladybird Beetle.* — Adult feeds on scale insects and aphids.

*Gall Insect.* — The developing larvæ cause galls from which ink is made.

### 2. Household Pests

*House Fly.* — Adult carries typhoid, tuberculosis, and summer complaint and other intestinal diseases. To exterminate, it is necessary to prevent breeding and kill overwintering flies.

*Mosquito.* — Adult carries malaria and yellow fever. May be exterminated by destroying the breeding places. See page 243.

*Body louse.* — Adult carries typhus. Insects may be killed by sterilizing infected clothing and by bathing patients in an antiseptic solution.

*Flea on Rats.* — Adult carries bubonic plague. Kill the rats.

*Clothes Moth.* — Larvæ eat clothing: wool, fur, etc. They may be controlled by shaking or brushing the clothing, and exposing it to the sun. The use of camphor or naphthaline with clothing which is packed away deters the moth from laying its eggs there.

*Buffalo Carpet-Beetle.* — Larva eats carpets. Spray benzine in the cracks in the floor and on the carpet.

*Cockroach.* — Adults are scavengers and are numerous around sinks and where food is kept. They may be exterminated with poison bait. Cleanliness is necessary.

### 3. Garden and Fruit Tree Pests

*Potato Beetle.* — Larva eats leaves of the potato plant. Spray infected plants with arsenate of lead or Paris green.

*Cabbage Butterfly.* — Larva eats leaves of cabbages and may be destroyed by a spray of arsenate of lead or Paris green.

*Hawk Moths.* — Larva feeds on leaves of grape and tomato vines. Spray.

*Rose Beetles.* — Adults feed on leaves and blossoms of the rose. Spray with a soap solution.

*Codling Moth.* — Larva injures apples and pears. Spray with arsenate of lead at the time petals fall.

*San José Scale.* — Adults suck juices from the leaves and young twigs of fruit trees. Killed by ladybird beetles and fumigation.

*Aphids.* — Adult females suck juice from leaves and young twigs. Spray with nicotine sulphate.

*Boll-worm* or *Corn Worm.* — Larva lives in the ears of corn.

*European Corn Borer.* — Feeds on stalks, roots, and ears of corn plant. Controlled by burning cornstalks in the fall.

### 4. Forest and Shade Tree Pests

*Tussock Moth.* — Larva eats leaves of shade and fruit trees. Destroy egg masses and spray in early spring.

*Gypsy Moth.* — Damage and extermination the same as for tussock moth.

*Forest Tent Caterpillar.* — Larva eats leaves of shade and fruit trees. Destroy nests and spray.

**Summary.** — We find first that because of numerous adaptations found in protective resemblance, mimicry, communal life, and symbiotic relationships that insects are the dominant forms on the earth to-day.

Secondly, because they are so numerous and carry certain diseases insects are of much economic importance. Not only do they take toll of one tenth or more of the world's plant food supply but they are responsible for all yellow fever and malaria as well as most of our typhoid, dysentery, and bubonic plague.

**Problem Questions.** — 1. Explain protective and aggressive resemblance.

2. What is warning coloration?
3. What is mimicry?
4. Describe the communal life of the honeybee.
5. What is symbiosis? Explain.

6. Explain how mosquitoes do harm. How may they be controlled?

7. Discuss the methods for prevention of yellow fever.

8. Make a balance sheet giving harm and good caused by insects.

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# XXI. THE MOLLUSKS

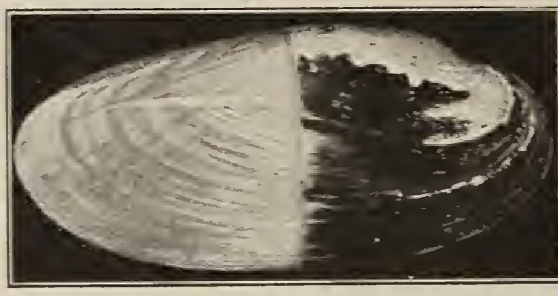
***Problem.*** *A study of mollusks and their enemies with reference to their economic importance.* (*Laboratory Manual, Prob. XXXIII; Laboratory Problems, Prob. 119.*)

To some high school pupils a clam or oyster on the "half shell" is a familiar object. The soft "body" of the animal lying between the two protecting "valves" of the shell gives the name to this group (Latin *mollis* — soft). Most mollusks have a shell composed mostly of lime, either bivalve (two-valved), as the oyster, clam, mussel, and scallop, or univalve (with one valve), as the snail. Usually the univalve shell is spiral in form. Among nature's most beautiful objects are the spiral shells of some marine forms. Other mollusks, for example the garden slug, have no shell whatever, and one highly specialized form, the squid, has an internal shell.

The limy shell, when present, is formed from the outer surface and edge of a delicate body covering called the *mantle.* The mantle may be found in the opened oyster or clam sticking close to the inside of the valve of the shell in which the body rests. Between the mantle and the body of the clam or oyster is a space, the *mantle cavity,* in which hang the platelike striated *gills.* By means of cilia on the inner surface of the mantle and on the gills a constant current of water is maintained through the mantle cavity, bearing oxygen to the gills and carbon dioxide away from them. This current of water passes, in most mollusks, into and out from the mantle cavity through the *si'phons;* the muscular tubes forming the "neck" of the "soft clam" are examples of such organs.

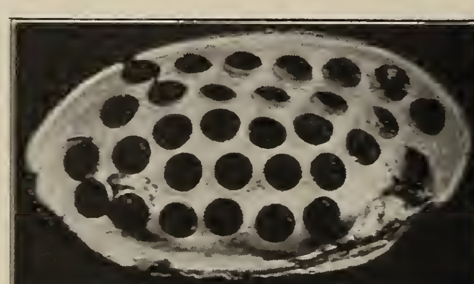
The food of clams or oysters consists of tiny organisms which are carried in the current of water to the mouth of the animal, this water current being maintained in part by the action of cilia on the palps or liplike flaps surrounding the mouth. A single muscular foot enables the clam to move about slowly.

The shallow water of bays where clams and oysters live, literally swarms with microscopic organisms which find the conditions for growth ideal. The tiny plants living there get food from the organic wastes brought down by the rivers. The carbon dioxide from the thousands of species of fish, mollusks, crustaceans, worms, and other forms of animal life gives them another source of raw food material. The sunlight penetrating through the shallow waters supplies the energy for making the food. Thus conditions are ideal for rapid multiplication; hence the water becomes alive with the lower forms of plant life, among which are always found bacteria, both harmless and harmful. In feeding upon these plants, mollusks take in many bacteria; man feeds on the mollusks, and, if he eats them raw, may eat living bacteria as well. If the germs of typhoid fever are present, disease may result. As a matter of fact, epidemics of typhoid fever have been traced to such sources.



Shell of fresh-water clam, the left half polished to show the prismatic layer from which buttons are made.

**Some Common Mollusks.**— The fresh-water clam, a common resident in the shallow water of inland ponds and rivers, has been sought in the making of pearl buttons. This industry is so important that it has depleted the number of adult clams in our Middle West; and the states affected and the United States government have undertaken the study of the life habits of these animals with a view to restocking the rivers. The development of the fresh-water clam or mussel is complicated. The egg develops into a free-swimming larval form which fastens to the gill of a



Clam shell after the removal of disks for making buttons.

fish and there lives as a parasite until almost mature. Then it drops off into the sand of the river or lake where it spends the rest of its life.

**The Oyster.** — Oysters are never found in muddy water, for they would be quickly smothered by the sediment. They cling to stones or shells or other objects which project a little above the bottom. Here food is abundant and oxygen is obtained from the air in the water surrounding them. Hence oyster raisers throw oyster shells into the water to make places of attachment for the young oysters.


Round clam (*Venus merceneria*): *AAM*, anterior adductor muscle; *ARM*, anterior retractor muscle; *PAM*, posterior adductor muscle; *PRM*, posterior retractor muscle; *F*, foot; *C*, cloacal chamber; *IS*, incurrent siphon; *FS.*, excurrent siphon; *EO*, heart; *G*, gills; *M*, mantle; *DGL*, digestive glands; *S*, stomach; *I*, intestine; *P*, palp; *R*, posterior end of digestive tract.

In some parts of Europe and of this country where oysters are raised artificially, stakes or brush are sunk in shallow water so that the young oysters, after the free-swimming stage, may find some object to which they can fasten and escape the danger of smothering on the bottom. After the oysters are a year or two old, they are taken up and planted in deeper water as seed oysters. At the age of three and four years they are ready for the market.

The oyster industry is very profitable, amounting to over $15,000,000 a year during the last decade. Hundreds of boats and thousands of men are engaged in dredging for oysters. Three of the most important of our oyster grounds are Long Island Sound, Narragansett Bay, and Chesapeake Bay.

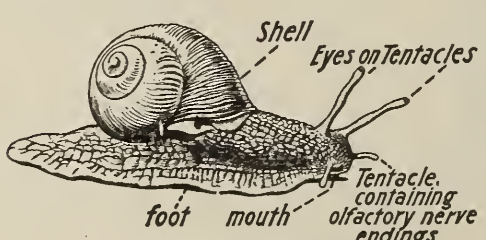
Sometimes oysters are artificially "fattened" by placing them near the mouths of fresh-water streams. These streams often

contain sewage. As this is a menace to health, it is evident that state and city supervision ought to be exercised not only to forbid the sale of shellfish which come from contaminated localities, but also to prevent the planting of oysters or other mollusks in the neighborhood of the openings of sewers or polluted rivers.

**Clams.** — Other bivalve mollusks used for food are clams and scallops. Two species of the former are known to New Yorkers, one as the "round," the other as the "long" or "soft-shelled" clam. The round clam was called "quahog" by the Indians, who used the blue area of its shell as wampum, or money. Both species are prized for food. The clam industries of the eastern coast aggregate over $1,000,000 a year.

**Scallop.** — The scallop, another molluscan delicacy, forms an important fishery. Only the single adductor muscle is eaten, whereas in the clam and oyster all the soft parts of the body are used as food.

**Pearls and Pearl Formation.** — Pearls are prized the world over. It is a well-known fact that even in this country pearls of some value are found occasionally within the shells of such common bivalves as the fresh-water mussle and the oyster. Most of the finest pearls, however, come from the waters around Ceylon. If a pearl is cut open and examined carefully, it is found to be a deposit of the mother-of-pearl layer of the shell around some central structure. It has been believed that any foreign substance, as a grain of sand, might irritate the mantle at a given point, thus stimulating it to secrete around the substance. It now seems likely that most perfect pearls are due to the growth within the mantle of the clam or oyster of certain parasites, which are stages in the development of the flukeworm. The irritation thus set up in the tissue causes mother-of-pearl to be deposited around the source of irritation, with the subsequent formation of a pearl.



A common snail.

**Gastropods.** — Snails, whelks, slugs, and the like are called *gas'tropods* (stomach-footed) because the foot occupies so much space that most of the organs of the body, including the stomach, are covered by it. Most gastropods are partly covered by a more or less spirally formed shell which has but one valve, in which the body is twisted spirally. In the garden slug, the mantle does not secrete an external shell, and the naked body is symmetrical.

Gastropods of various species do considerable damage, some in the garden, where they feed upon young plants, and others in the sea, where they bore into the shells of other living mollusks in order to get out the soft part of the body which they use as food.

The squid. One fourth natural size.

**Cephalopods.** — Another class of mollusks are those known as *cephalopods* (sĕf′a-lō-pŏdz). The name means head-footed. As the Figure shows, the mouth is surrounded with a circle of tentacles. The shell is internal or lacking. The so-called pen of the cuttlefish is all that remains of the shell in that form. A cuttlefish is strangely modified for the life it leads. It moves rapidly through the water by squirting water from the siphon. It can seize its prey with the suckers on its long tentacles and tear it in pieces by means of its horny, parrotlike beak. It is protected from its enemies and enabled to catch its prey because of its ability to change color quickly. In this way the animal simulates its surroundings. The cuttlefish has, near the siphon, an ink bag which contains the black sepia. A few drops of this ink squirted into the water may effectually hide the animal from its enemy.

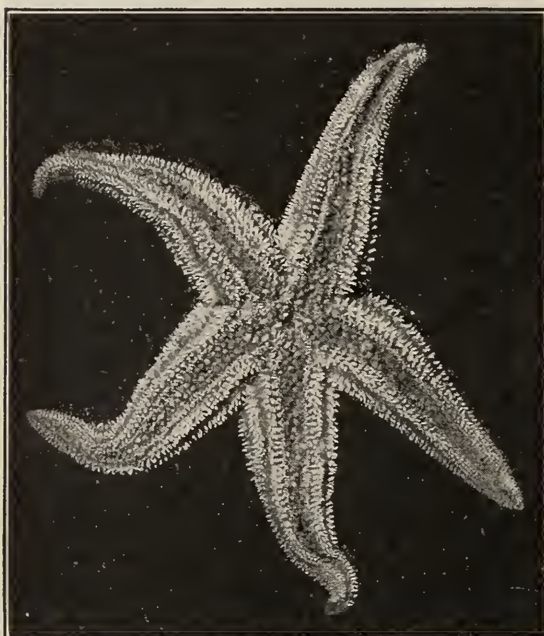
To this group of animals belong also the octopus, or devilfish, a cephalopod known to have tentacles over thirty feet in length; the paper nautilus; and the pearly nautilus, the latter made famous by our poet Holmes.

**Habitat of the Mollusks.** — Mollusks are found in almost all parts of the earth and sea. They are more abundant in temperate localities than elsewhere, but live also in tropical and polar countries. They are found in all depths of water, but by far the greatest number of species live in shallow water near the shore. The cephalopods stay near the surface of the ocean, where they prey upon small fish. The food supply evidently determines to a large extent where they live. Some mollusks are scavengers; others feed on living plants.

We have found in the forms of mollusks studied that almost all of them live in the water. There is one large group which forms a general exception to this, certain of the snails and slugs called *pul′monates.* But even these animals are found in damp localities, and during a drought they become inactive and remain within their shells. The European snail imported to this country

as a table delicacy exists for months by plugging up the aperture of its shell with a mass of slimy material which later hardens, thus protecting the soft body within.

**Economic Importance.** — In general the mollusks are of much economic importance. The bivalves especially form an important source of our food supply. Many of the mollusks also make up an important part of the food supply of bottom-feeding fishes. On the other hand, some mollusks, as *nat'ica*, bore into the shells of other mollusks and eat the animals inside. Some boring mollusks, for example the shipworm, do much damage to wharves, where they make their homes in the piles. Still others bore holes in soft rock and live there.



Ventral or under surface of the starfish. The dark circle in the middle is the mouth, from which radiate the five ambulacral grooves, each filled with four rows of tube feet. Photograph half natural size, by Davison.

The shells of mollusks are used to a large extent in manufactures and in the arts, and they are still used as money in some parts of the world. Sepia comes from the cuttlefish.

**The Starfish.** — By far the most important enemy of the oyster and other salt-water mollusks is the starfish. The common starfish, as the name indicates, is shaped like a five-pointed star. A skeleton of lime which is made up of thousands of tiny plates gives shape to the body and arms. Slow movement is effected by means of tiny suckers, called *tube feet.* Breathing takes place through the skin. The mouth is on the under surface of the animal, and, when feeding, the stomach is protruded and wrapped around its prey. The body of the starfish, as well as that of the sea urchin and others of this group, is spiny; hence the name *Echinoderm* (ē-kī'nō-dûrm), which means spiny-skinned, is given to the group.

**Food of the Starfish.** — Starfish are enormously destructive of young

clams and oysters, as the following evidence, collected by Professor A. D. Mead of Brown University, shows. A single starfish was confined in an aquarium with fifty-six young clams. The largest clam was about the length of one arm of the starfish, the smallest about ten millimeters in length. In six days every clam in the aquarium was devoured.

In order to capture and kill mollusks, the starfish wrap themselves around the valves of the shell and actually pull them apart by means of their tube feet, some of which are attached to one valve and some to the other of their victim. Once the soft part of the mollusk is exposed, the stomach envelops it and covers it with the secretions of digestive glands, and it is rapidly digested and changed to a fluid.

Hundreds of thousands of dollars' damage is done annually to the oysters in Connecticut alone by the ravages of starfish. During the summer months the oyster boats are to be found at work raking the beds for starfish, which are collected and thrown ashore by the thousands

### Classification of Mollusks (Mollusca)

Class I. *Pelecyp'oda* (*Lamellibranchia'ta*). Soft-bodied unsegmented animals showing bilateral symmetry. Bivalve shell, platelike gills. Examples: clam, scallop, oyster, and fresh-water mussel.

Class II. *Gastrop'oda.* Soft bodies asymmetrical; univalve shell or shell absent. Some forms breathe by gills, others by lunglike sacs. Examples: pond snail, land snail, and slug.

Class III. *Cephalop'oda.* Bilaterally symmetrical mollusks with mouth surrounded by tentacles. Shell may be external (nautilus), internal (squid), or altogether lacking (octopus). Examples: squid, octopus.

**Summary.** — Mollusks are characterized by a soft body, a mantle which secretes the shell when present, and a muscular foot. Some are of economic importance as food, as the clam, scallop, and oyster.

**Problem Questions.** 1. How do mollusks move?

2. How do mollusks breathe?
3. On what kind of food do mollusks feed?
4. How are pearls formed?
5. How do starfish eat? Explain fully.

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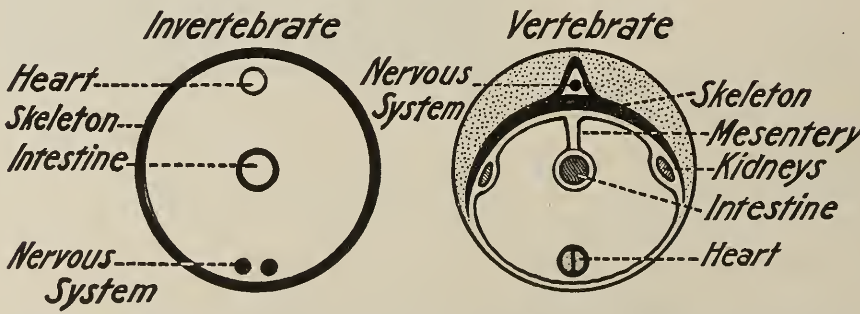
# XXII. THE VERTEBRATE ANIMALS

**Increasing Complexity of Structure and of Habits in Plants and Animals.** — In our study of biology so far we have attempted to get some notion of the various factors which act upon and interact with living things. We have learned something about the various physiological processes of plants and animals, and have found them to be in many respects identical. We have examined a number of forms of plants and have found all grades of complexity, from the one-celled plant, bacterium or pleurococcus, to the complicated flowering plants of considerable size and with many organs. So in animal life the forms we have studied, from the Protozoa upward, there is constant change, and the change is toward greater complexity of structure and of function. A worm is simpler in structure than an insect, and shows by its sluggish actions that it is not so high in the scale of life as its more lively neighbor.




Cross section through an invertebrate animal and a vertebrate animal.

We are already awake to the fact that we are better equipped in the battle for life than our more lowly neighbors, for we are *thinking* creatures, and can change our surroundings at will, while the lower forms of animals are largely controlled by stimuli which come from without; temperature, moisture,

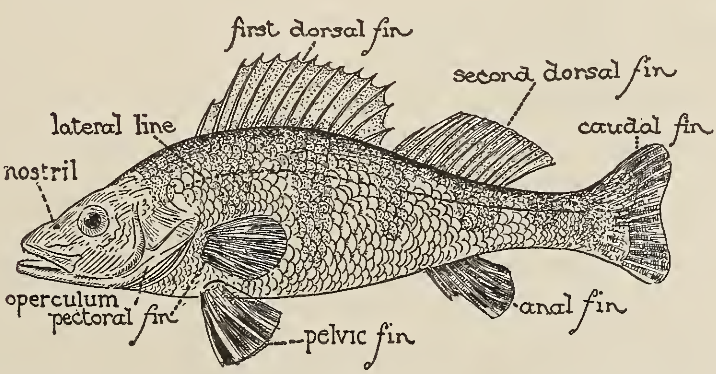
light, the presence or absence of food, — all these result in movement and other reactions.

Our next study will be of a group of animals called *ver'tebrates,* because they have a bony vertebral column, made up of pieces of bone joined one to another, forming a flexible yet strong support for the muscles and protecting the delicate central nervous system. This kind of an *endoskeleton,* or inside skeleton, is possessed by fishes, frogs, turtles, snakes, birds, and mammals, such as the dog, the cat, and man. We begin with the study of some types of various kinds of vertebrates, with a view to the better understanding of man.

## Fishes

**Problem.** *To determine how a fish is fitted for the life it leads. (Laboratory Manual, Prob. XXXIV; Laboratory Problems, Probs. 133 to 139.)*

**The Body.** — One of our common fresh-water fishes is the perch. The body of the perch, like that of many other fishes,




Side view of a fish (a perch). There are two pectoral and two pelvic fins, one on each side.

runs insensibly into the head, the neck being absent. The long, narrow body, pointed at the anterior end, with its smooth surface, makes the fish admirably adapted for swimming. Certain cells in the skin which secrete mucus or slime, and the position of the scales, overlapping in a backward direction, are other adaptations which aid the fish in passing through the water.

The color of many fishes, olive above and gray or bright silver below, is protective. Can you see how?

**The Appendages and their Uses.** — The appendages of the fish consist of paired and unpaired fins. The paired fins are four in number, and are believed to correspond in position and structure with the paired limbs of a man. In the Figure (p. 261) locate the paired *pectoral* and *pelvic* fins. Compare a living fish with the Figure, and find the *dorsal, anal,* and *caudal* fins. How many unpaired fins are there? The study of a fin shows that it is composed of a thin membrane which is held in shape and stiffened by long slender rods of bone or cartilage called fin rays. The fin is light and strong, and, as powerful muscles are attached to it, can push against the water with sufficient force to move the body forward. Note that the dorsal fin has spinelike rays, while the fin rays of the caudal fins are flexible. Do you find any fins in which both kinds of rays occur?

The flattened, muscular body of the fish, tapering toward the caudal fin, is moved from side to side with an undulating motion which results in the forward movement of the fish. This movement is almost identical with that of an oar in sculling a boat. Turning movements are brought about by use of the lateral fins in much the same way as a boat is turned. We notice that the dorsal and anal fins are evidently useful as balancing and steering organs.

**The Senses.** — The position of the eyes at the sides of the head is an evident advantage to the fish. Why? The eye is globular in shape. As such an eye has been found to be very near-sighted, it is likely that a fish is unable to perceive objects at any great distance from it. The eyes are unprotected by eyelids, but their tough outer covering and their position at the sides of the head afford some protection.

Feeding experiments show that a fish becomes aware of the presence of food by smelling it as well as by seeing it. The nostrils of a fish are organs for smelling. They are little pits, which differ from our nostrils in that they are not connected with the mouth cavity. In the catfish, the *barbels*, or horns, receive sensations of smell and taste. The sense of smell in a

fish is not quite the same as ours, for it perceives only substances that are dissolved in the water in which it lives. The senses of taste and touch appear to be less developed than the other senses.

Along each side of most fishes is a line of tiny pits, provided with sense organs and connected with the central nervous system. This area, called the *lateral line,* is believed to be sensitive to mechanical stimuli of certain sorts. The "ear" of the fish is under the skin and serves partly as a balancing organ.

The tongue in most fishes is wanting or very slightly developed.

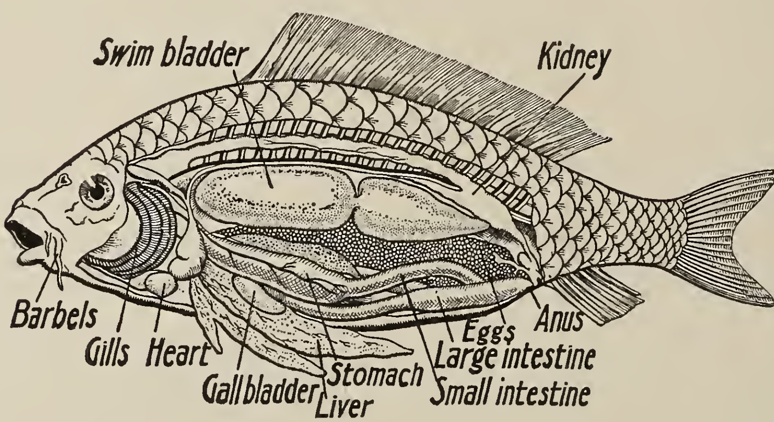
**Breathing.** — A fish, when swimming quietly and when at rest, seems to be biting even if no food is present. It will be found that a current of water enters when the mouth is opened and is pushed back by the closing of the mouth and out through slits located on each side back of the head. Investigation shows us that under the broad, flat plate, or *oper'culum*, covering these slits on each side, lie several long, feathery, red structures, the *gills*. By the movements of the mouth a current of fresh water is made to pass over the gills.

**Gills.** — In most fishes we find five pairs of gills. The foundation of the gill, or the *gill arch*, is composed of several pieces of bone which are hinged in such a way as to give great flexibility. Covering the bony framework, and extending from it, are numerous delicate *filaments* of flesh, covered with a very delicate membrane or skin. In each of these filaments are two blood vessels; in one blood flows downward and in the other, upward. While in the gill filament the blood is separated by a thin membrane from the oxygen dissolved in the water bathing the gills. An exchange of gases through the walls of the gill filaments results in a loss of carbon dioxide and a gain of oxygen by the blood.

*Gill Rakers.* — If we open wide the mouth of any large fish and look inward, we find that the mouth cavity leads to a funnel-like opening, the gullet. On each side of the gullet we can see the gill arches holding the red filament. These delicate structures are guarded on the inner side by a series of sharp-pointed structures, the *gill rakers*. In some fishes in which the

teeth are not well developed, there is a greater development of the gill rakers, in which case they are used to strain out food or small organisms from the water which passes over the gills. (See Figure, p. 266.)

**Digestive System.** — The gullet leads directly into a baglike stomach. There are no salivary glands in the fishes. There is, however, a large liver, which appears to be used as a digestive gland. The liver contains a good deal of oil and therefore is in some fishes, as the cod, of considerable economic importance. Many fishes have outgrowths like a series of pockets from the intestine. These structures, called the *pylor'ic cœca* (sē'ka), are believed to secrete a digestive fluid. The intestine ends at the vent, or




Anatomy of a fish (a carp).

anus, which is usually located on the ventral side of the fish, immediately in front of the anal fin.

**Swim Bladder.** — An organ of unusual significance, called the *swim bladder*, occupies the region just dorsal to the food tube. In young fishes of many species this is connected by a tube with the anterior end of the digestive tract. In some forms this tube persists throughout life, but in other fishes it becomes closed, and makes a thin, fibrous cord. The size of the swim bladder can be changed through the contraction or expansion of its walls. The fish uses it to make changes in the space it occupies, so that the water displaced will equal its own weight. Thus the weight of the fish is supported, no matter at what depth it wishes to remain.

**Circulation of the Blood.** — In the vertebrate animals the blood circulates around the body, through a more or less closed system of tubes. In fishes the heart is a muscular organ, with two connecting chambers: a thin-walled *au'ricle*, or receiving chamber, and a thick-walled muscular *ven'tricle* from which the blood is forced out. The blood is pumped from the heart to the gills, where it loses carbon dioxide and receives oxygen; it then passes on to

other parts of the body, until it reaches very tiny tubes called *cap'illaries.* From the capillaries the blood returns, in veins of gradually increasing diameter, to the heart again. During its course around the body some of the blood passes through the kidneys and is there relieved of its nitrogenous waste. (See Chapter XXVII.)

Circulation of blood in the fish is rather slow. The temperature of the blood is nearly that of the water in which the fish lives.

**Nervous System.** — As in all other vertebrate animals, the central nervous system of the fish consists of the *brain* and *spinal cord,* which are covered by cartilage or bone for protection. The brain has nerves leading to the organs of sight, taste, and smell, to the ear, and to such parts of the body as possess the sense of touch. Nerve cells located near the outside of the body send messages to the brain, where they are received as sensations. Cells of the central nervous system, in turn, send out messages which result in the movement of muscles.

**Skeleton.** — In the vertebrates, of which the bony fish is an example, the skeleton is under the skin, and is hence called an *endoskeleton.* It consists of a skull, the vertebral column, the ribs, and other spiny bones to which the unpaired fins are attached. The paired fins are attached to the spinal column by two collections of bones, known respectively as the *pectoral* and *pelvic girdles.* The bones serve in the fish for the attachment of powerful muscles, by means of which locomotion is accomplished. In most fishes the *exoskeleton,* too, is well developed, modifications appearing from scales to complete armor.

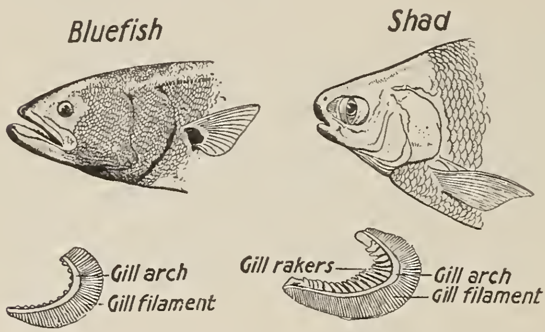
***Problem.*** *To determine some of the relations of fishes to their food supply. (Laboratory Manual, Prob. XXXV; Laboratory Problems, Prob. 139.)*

**Food of Fishes.** — We have already seen that in a large balanced aquarium the plants furnish food for the tiny animals and a few of the larger ones, — for example, snails. The smaller animals are eaten by larger ones until the largest of all is fed. The nitrogen balance is maintained through the wastes of the animals and their death and decay.

The ocean is a great balanced aquarium in which the upper layer of water is crowded with all kinds of little organisms, both plant and animal. Although microscopic in size or barely visible to the eye, like the tiny crustaceans, they serve as food for big fishes. The menhaden [1] (bony, bunker, mossbunker of

[1] It has been discovered by Professor Mead of Brown University that the increase in starfish along certain parts of the New England coast was in part due to overfishing of menhaden, which at certain times in the year feed almost entirely on the young starfish.

our coast), the shad, and others, depend upon these minute organisms for food. Such fishes have small mouths and very large gill rakers which strain the water as it passes over the gills and hold back the food particles. Other fishes are bottom feeders, as the blackfish and the sea bass, living almost entirely upon mollusks and crustaceans. Still others are hunters, feeding upon smaller species of fish or even upon their weaker brothers. Such are the bluefish, and the squeteague or weakfish. Such a fish must go after its prey and seize it with its mouth, as it has no grasping organs except its teeth. Consequently we find a large mouth in which the teeth are sharp, pointed, numerous, and adapted for holding living prey. The gill rakers are small or lacking.



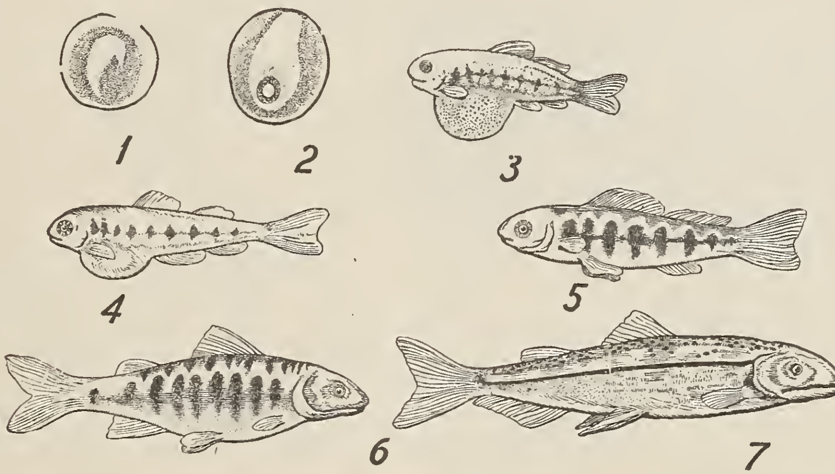
Comparative size of mouth in bluefish (large mouth) and shad (small mouth and large gill rakers).

What is true of salt-water fish is equally true of those inhabiting our fresh-water streams and lakes. It is one of the greatest problems of our Bureau of Fisheries to discover this relation of various fishes to their food supplies so as to aid in the conservation and balance of life in our lakes, rivers, and seas.

**The Egg-laying Habits of the Bony Fishes.** — The eggs of most bony fishes are laid in great numbers. The number varies from a few thousand in the trout to many hundreds of thousands in the shad and several millions in the cod. The time of spawning is usually spring or early summer. After the eggs are laid the male usually deposits milt, consisting of millions of sperm cells, in the water just over the eggs. The sperm cells move rapidly through the water, find the egg cells, and fertilization follows. Some fishes, as sticklebacks, sunfish, toadfish, etc., make nests, but usually the eggs are left to develop by themselves, sometimes attached to some submerged object, but more frequently free in the water. Some eggs which have a

tiny oil drop, are buoyed up to the surface, where the heat of the sun aids development. Both eggs and developing fish are exposed to many dangers, and are eaten, not only by birds, fish of other species, and other water inhabitants, but also by their own relatives and even parents. Consequently a very small percentage of eggs ever reach maturity.

**Life History of the Yellow Perch.** — This common fish has been caught by almost every boy who reads these lines. It frequents inland ponds and streams in the northeastern part




Life history of a fish: 1, 2, developing eggs; 3, 4, young with yolk sac; 5, 6, 7, later stages after the yolk sac is absorbed.

of the United States. Large numbers of them roam about in schools so that if one locates a school he may be fairly sure of a good catch.

Perch lay their eggs in masses or strings, often several hundreds or even thousands being found in a single mass. The time of egg laying is in March or April. After fertilization the eggs segment, forming a mass of cells, which gradually assume the form of a tiny fish with a yolk sac, containing food, on its ventral surface. Eventually the yolk is absorbed by the young fish and a few weeks from the time of hatching we find it able to take care of itself.

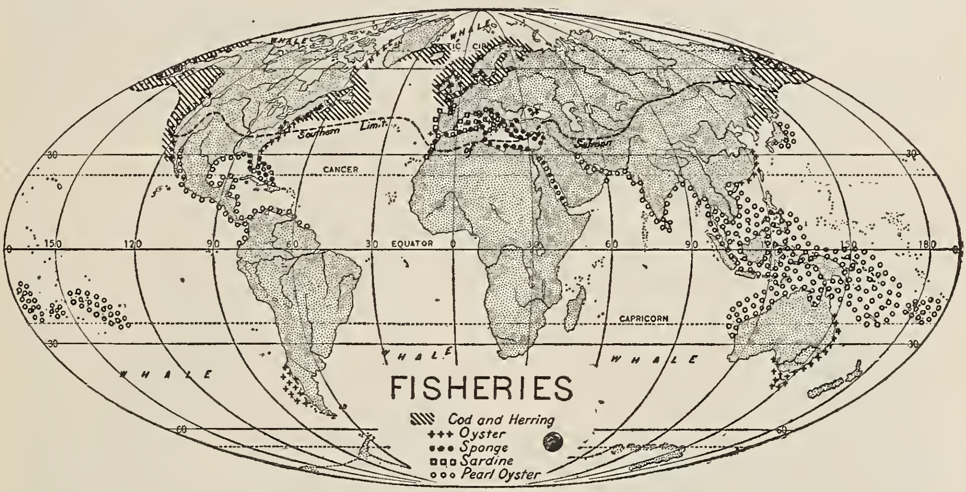
**Life History of the Chinook Salmon.** — The Chinook salmon of the Pacific coast is the salmon used in the western canning

industry. It is a fine, big fish, of about four or five years, when it reaches maturity, leaves the Pacific, and enters the Columbia or one of the other big rivers of the western slope to journey to the cool mountain streams, where it spawns. During this journey of from one thousand to two thousand miles, it does not eat, swims against a strong current, and leaps high falls. The salmon start in early spring. Large numbers of them pass up the rivers together and reach the spawning beds in late summer in a very exhausted condition. Here the fish remain until the temperature of the water falls to about 54° Fahrenheit. Shallow nests are made in the gravel by the male. The eggs and milt are then deposited, and the old fish die, leaving the eggs to be hatched out thirty or forty days later by the heat of the sun's rays. The young salmon pass down stream to the ocean, where they live until mature, when they return to the rivers to lay their eggs.

Salmon leaping a fall on the way to their spawning beds.

**Migration of Fishes.** — Some fishes change their habitat at different times during the year, moving in vast schools northward in summer and southward in the winter. In a general way such migrations follow the coast lines. Examples of the migratory fish are the cod, menhaden, herring, and bluefish. The migrations are due to temperature changes, to the seeking after food, and to the spawning instinct. The salmon, shad, sturgeon, and smelt pass up rivers from the ocean to lay their eggs. Some fish migrate to shallower water in the summer and to deeper water in the winter; here the reason for the migration is doubtless the change in temperature. The instinct of salmon and other species to go into shallow rivers to deposit their eggs has been made use of by man. At the time of the spawning migration the salmon are taken in vast numbers.

**Economic Importance.** — Fish are of great importance as food. The herring fisheries have always been a source of wealth to the inhabitants of northern Europe. The banks and shallows of the coast of Newfoundland abound in cod. The cod fisheries of the United States net over $20,000,000 a year, the salmon fisheries over $16,000,000, the shad at least $1,500,000, the smelt fishery nearly $150,000. The total annual value of the fisheries of the United States is over $50,000,000.




The bones of fish are ground and made into fertilizers. Soap is made from the oil of fish. Cod liver oil is used as a medicine. Glue is made from the skin, fins, etc.

***Problem.*** *To learn something of the artificial propagation of fishes. (Laboratory Manual, Prob. XXXVI.)*

**The Work of National and State Governments in protecting and propagating Food Fishes.** — But the profits from the fisheries are steadily decreasing because of the yearly destruction of untold millions of eggs which might develop into adult fish.

Fortunately, the United States government through the Bureau of Fisheries, and various states by wise protective laws and by artificial propagation of fishes, are beginning to turn the tide. Certain days of the week the salmon are allowed to pass up the Columbia unmolested. Closed breeding seasons

protect our trout, bass, and other game fish. The catching of certain fish under a stated size is prohibited also. Many fish hatcheries, both national and state, are engaged in artificially fertilizing millions of eggs of various species and protecting the young fry until they can be placed in ponds or streams at a size when they can take care of themselves. For artificial fertilization the ripe eggs of a female are squeezed out into a pan of water; in

Work of a fish hatchery: fertilization of eggs. Two men with dipnets are lifting male and female whitefish from crates into the tub at the right. The spawntaker presses out the eggs and the milt into a pan, which is passed on to the man at the left. After washing and hardening, the eggs are removed to the hatchery.

a similar manner the milt or sperm cells are obtained, and poured over the eggs. The fertilized eggs are carefully protected, and, after hatching, the young fry are kept in ideal conditions until later they are shipped, sometimes thousands of miles, to their new home.

It is feared in many cases that assistance comes too late, for at the present rate of destruction some of our most desirable food fishes will soon be extinct. The sturgeon, the eggs of which are used in the manufacture of the delicacy known as *caviare*, is an example of a fish that is almost extinct in this

part of the world. The shad is found in fewer numbers each year, and in fewer rivers as well. The salmon will undoubtedly soon meet the fate of other fishes which are taken at the spawning season, unless conservation of a radical sort takes place.

### Classification of Fishes

Subclass I. *Elasmobran'chii.* Fishes having a skeleton formed of cartilage which has not become hardened with lime; gills communicating with the surface of the body by separate openings instead of having an operculum. Examples: sharks, rays, skates.

Sand shark, an elasmobranch. Note the slits leading from the gills. From photograph loaned by the American Museum of Natural History.

Subclass II. *Ganoi'dei.* Fishes having bodies protected by a series of platelike scales of considerable strength. Example: gar pike.

Sturgeon, a ganoid.

Subclass III. *Teleos'tei.* Fishes having a bony skeleton; gills protected by an operculum. These tel'eosts comprise 95 per cent of all living fishes.

Subclass IV. *Dip'noi.* A very small group of fishes that use the swim bladder as a lung. They are thus in some respects like amphibians. They live in tropical Africa, South America, and Australia, where rivers and lakes go dry for part of the year.

**Summary.** — Fish are animals adapted to an aquatic life by having a smooth, more or less cigar-shaped body, with modi-

fied flattened appendages called fins and a powerful caudal fin which serves with the muscles of the body as an organ of locomotion. Gills absorb oxygen which is dissolved in the water and give off carbon dioxide. Fishes usually lay large numbers of eggs, and many of the young die before reaching maturity. The egg-laying habits often take fish, as the salmon, thousands of miles up rivers to lay their eggs. Fishes are of great economic importance as food and need protection from government and individuals alike.

**Problem Questions.** — 1. What adaptations enable a fish to swim? to escape its enemies? to catch its prey?

2. Discuss the egg-laying habits of some specific fishes. How do you account for the differences in habits?

3. Classify the fishes.

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## Amphibia. The Frog

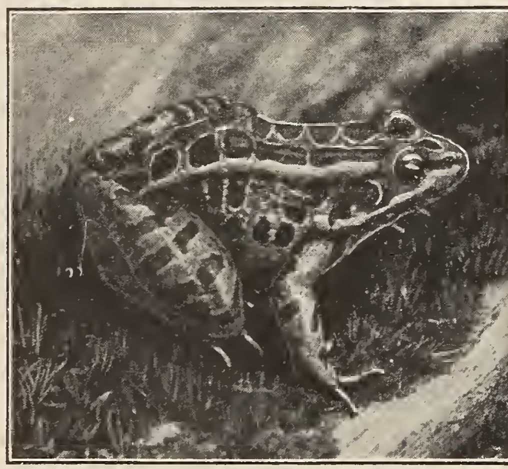
***Problem.*** *To discover some adaptations in a living frog. (Laboratory Manual, Prob. XXXVII; Laboratory Problems, Probs. 140 to 145.)*

**Adaptations for Life.** — The most common frog in the eastern part of the United States is the leopard frog. It is recognized by its greenish brown body with dark spots, each spot being outlined in a lighter colored background. In spite of the apparent lack of harmony with its surroundings, its color, on the contrary, appears to give almost perfect protection. In some species of frogs the color of the skin changes with the surroundings of the frog, another means of protection.

Adaptations for life in the water are numerous. The ovoid

body, the head merging into the trunk, the slimy covering (for the frog is provided, like the fish, with mucus cells in the skin), and the powerful legs with webbed feet, are all evidences of the life which the frog leads.

**Locomotion.** — You will notice that the appendages have the same general position on the body and same number of parts as do your own (upper arm, forearm, and hand; thigh, shank, and foot, the latter much longer relatively than your own). Note that while the hand has four fingers, the foot has five long toes, connected by a web to push against the water when swimming. As the frog lives on both land and water its powerful, long legs are adapted for jumping as well as for swimming. When at rest, these legs are doubled up close to the body ready to give a quick spring forward. As they are very long and attached to powerful muscles, the frog moves rapidly. The short arms are used to balance the body when at rest.



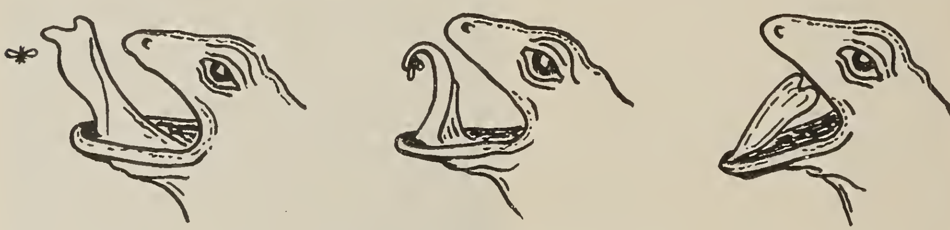
The leopard frog.

**Sense Organs.** — The frog is well provided with sense organs. The eyes are large, globular, and placed at the sides of the head. When the frog goes under water a delicate fold, called the *nic'titating membrane* (or third eyelid), is drawn over each eye. Frogs probably see moving objects best at a few feet from them. Their vision is much keener than that of the fish. The external ear (*tym'panum*) is located just behind the eye on the side of the head. Frogs hear sounds and distinguish various calls of their own kind, as is proved by the fact that they recognize the warning notes of their mates when any one is approaching. The inner ear has to do with balancing the body as it does in fishes and other vertebrates. Touch is a well-developed sense. Frogs respond to changes in temperature

under water, and go into a dormant state for the winter when the temperature of the air becomes colder than that of the water.

Taste and smell are probably not strong sensations in a frog or toad.

**Food Getting.** — The frog's mouth is large and the sticky tongue is long and flexible. It is attached to the front of the floor of the mouth and is thrown out with great rapidity to secure



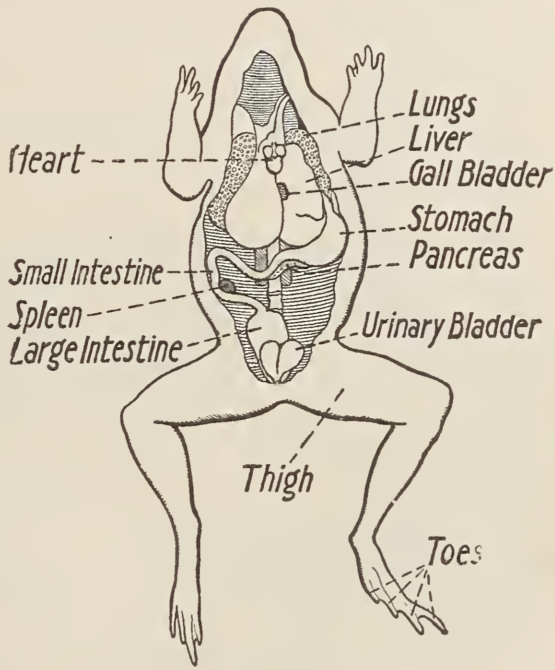
How a frog catches a fly.

living prey. Experience has taught these animals that moving things, insects, worms, and the like, make good food. These they swallow whole, the tiny teeth being used to hold the food.

**Breathing.** — The frog takes air into its mouth by lowering the floor of the mouth and pulling in air through the two nostril holes. Then the little flaps over the holes are closed, the floor of the mouth is raised, and the frog swallows this air, thus forcing it down into the baglike lungs. When the nostril flaps are lifted the air is forced out by the pressure of the body wall and the elasticity of the lungs. The lungs contain air spaces, the walls of which are filled with blood vessels. Some of the oxygen from the air passes through the walls into the blood, while some of the carbon dioxide of the blood in turn is passed into the air in the lung sacs. The skin also is provided with many tiny blood vessels which absorb oxygen and give off carbon dioxide. In winter, while the frogs are dormant at the bottom of the ponds, the skin is the only organ of respiration.

**The Food Tube and its Glands.** — The mouth leads like a funnel into a short tube, the *gullet*. On the lower floor of the mouth can be seen the slitlike *glottis* or opening into the trachea. The gullet widens almost at once into a long *stomach*, which in turn leads into a narrow, much coiled intestine. This widens

abruptly into the *cloa'ca* (Latin, sewer) into which open the *kidneys, urinary bladder,* and reproductive organs (*ovaries* or *spermaries*). Several *glands,* the function of which is to produce digestive fluids, open into the food tube. These digestive fluids by means of the ferments or enzymes contained in them, change insoluble food materials into a soluble form so that they may be absorbed through the walls of the food tube and become part of the blood. The glands (having the same names and uses as those in man) are the *salivary glands,* which pour their juices into the mouth, the *gastric glands* in the walls of the stomach, and the *liver* and *pancreas,* which open into the intestine. (See Digestion, chapter XXV.)



Internal organs of a frog.

**Circulation.** — The frog has a well-developed heart, composed of a thick-walled muscular ventricle and two thin-walled auricles. The heart pumps the blood through a system of closed tubes to all parts of the body. Blood enters the right auricle from all parts of the body; it then contains considerable carbon dioxide; the blood entering the left auricle comes from the lungs, hence it contains a considerable amount of oxygen. Blood leaves the heart through the ventricle, which thus pumps blood containing much and little oxygen. Before the blood from the tissues and from the lungs has time to mix, however, it leaves the ventricle and, by a delicate adjustment in the vessels leaving the heart, most of the blood containing much oxygen is passed to all the various organs of the body, while the blood deficient in oxygen, but containing a large amount of carbon dioxide, is pumped to the lungs.

In the cells of the body wherever work is done the process of burning or oxidation must take place, for by such means only is the energy necessary to do the work released. Food in the blood is taken to the muscle cells or other cells of the body and there oxidized. The products of the burning, chiefly carbon dioxide, and any other organic wastes given off from

the tissues must be eliminated from the body. As we know, the carbon dioxide passes off through the lungs and to some extent through the skin of the frog, while the nitrogenous wastes, poisons which must be taken from the blood, are eliminated from it in the kidneys.

**Problem.** *To learn about the development of a frog.* (*Laboratory Manual, Prob. XXXVI; Laboratory Problems, Probs. 146 to 148.*)

(*a*) *Conditions favorable for development.*

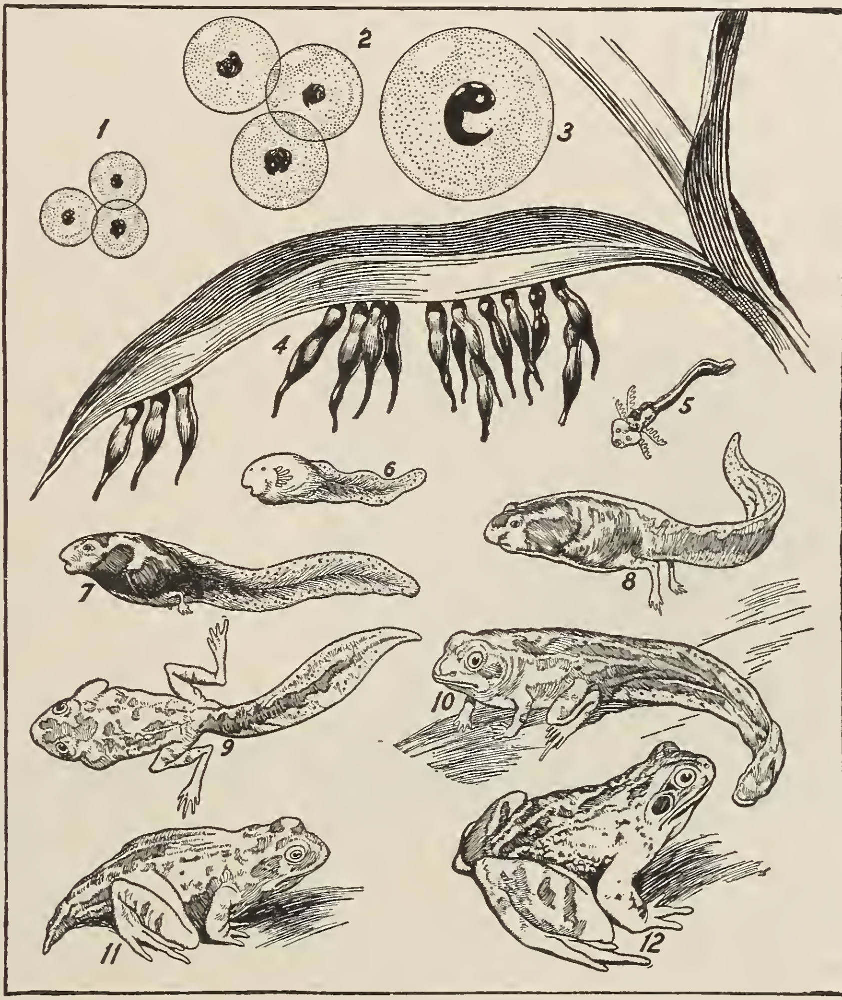
(*b*) *Metamorphosis.*

(*c*) *Development of a toad* (*optional*).

**Field and Home Work.** — During the first warm days in March or April, look for gelatinous masses of frogs' eggs attached to sticks or water weeds in shallow ponds. Collect some and keep in a shallow dish in a window at home until they hatch. Make experiments to learn whether temperature affects the development of the eggs in any way. Place eggs in dishes of water in a warm room, in a cold room, and in the ice box. Make observations for several weeks as to the rate of development of each lot of eggs. Also try placing a large number of eggs in one dish, thus cutting down the supply of available oxygen, and in another dish near by, under the same conditions of light and heat, place a few eggs with plenty of water. Do both batches of eggs develop with the same rapidity? In all these experiments be sure to use eggs from the same egg mass, so as to make sure that all are of the same age.

**Development.** — The eggs of the leopard frog are laid in shallow water in the early spring. Masses of several hundred, which may be found attached to twigs or other supports under water, are deposited at a single laying. Immediately before leaving the body of the female they receive a coating of jellylike material, which swells up after the eggs are laid. Thus they are protected from the attacks of fishes or other animals which might use them as food. The upper side of the egg is dark, the light-colored side being weighted down with a supply of yolk (food). The fertilized egg soon segments (divides and subdivides into many cells), and in a few days, if the weather is warm, it has grown into an oblong body which shows the form of a tadpole. Shortly after, the tadpole wriggles out of the jellylike case and begins life outside the egg. At first it remains attached to some water weed by means of a suckerlike projection; later a mouth is formed at this point, and the tadpole begins to

feed upon algae and other tiny water plants. At this time, about two weeks after the eggs were laid, gills are present on the outside of the body. Soon after, the external gills are replaced by gills which grow out under a fold of the skin which




Development of the frog: 1, 2, 3, eggs; 4, newly hatched tadpoles; 5, tadpole with external gills; 6 to 11, later stages; 12, frog.

forms an operculum somewhat as in the fish. Water reaches the gills through the mouth and passes out through a hole on the left side of the body. As the tadpole grows larger, legs appear. The hind legs grow out first. The tail is used as an organ for locomotion until the hind legs are ready.

Shortly after the legs appear, the gills are absorbed, and lungs take their place. At this time the young animal may be seen coming to the surface of the water for air. Changes in the diet of the animal also occur; the long, coiled intestine is transformed into a much shorter one. The animal, now insectivorous in its diet, becomes provided with tiny teeth and a mobile tongue, instead of the horny jaws used in scraping off algae. After the tail has been completely absorbed and the legs have become full grown, there is no further structural change, and the metamorphosis is complete.

In the leopard frog the change from the egg to adult is completed in one summer. In the green frog and bullfrog the metamorphosis is not completed until the beginning of the second summer. The large tadpoles of such forms bury themselves in the soft mud of the pond bottom during the winter.

The common toad.

**The Common Toad.** — One of the nearest allies of the frog is the common toad. The eggs, like those of the frog, are deposited in fresh-water ponds. The egg-laying season of the toad is later than that of the frog. The eggs are laid in strings, and as many as eleven thousand eggs have been laid by a single toad.

Toad tadpoles may be distinguished from those of the frogs, as they are darker in color, and have a more slender tail and a relatively larger body. The metamorphosis occupies only about two months in the vicinity of New York, but varies greatly with the temperature. During the warm weather the tail is absorbed with wonderful rapidity, and the change from a tadpole with no legs to a small toad living on land is often

accomplished in a few hours. This has given rise to the absurd story that it rains toads, because during the night thousands of young toads have changed their habitat from the water to the land.

The toad is of great economic importance to man because of its diet. No less than eighty-three species of insects, mostly injurious, have been proved to enter into its dietary. A toad has been observed to snap up one hundred and twenty-eight flies in half an hour. At a low estimate it could easily destroy one hundred insects a day for several months, and do an immense service to the garden during the summer. It has been estimated by Kirkland that a single toad may, on account of the cutworms that it kills, be worth $19.88 a season, if the damage done by each cutworm be estimated at only one cent. Toads also feed upon slugs and other garden pests.

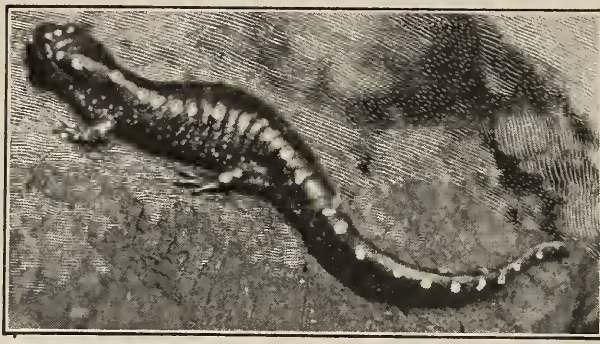
**Other Amphibians.** — The tree frogs (called tree toads) are familiar to us in the early spring as the "peepers" of the swamps. They are among the earliest of the frogs to lay their eggs. During adult life they spend most of their time on the trunks of trees, where they receive immunity from attack because of their color markings. The feet of the tree toad are modified for climbing by having little disks on the ends of the toes, by means of which it is able to cling to vertical surfaces.

Newt. From photograph loaned by the American Museum of Natural History.

Another common amphib'ian is the newt, a salamander. This smooth-skinned, four-limbed animal, often incorrectly called a lizard, passes its larval life in the water, where it breathes by means of external gills. Later it loses its gills, becomes provided with lungs, and comes out on land. Its coat, which was greenish in the water, changes to a bright orange color. In this condition we sometimes find newts crawling on wood roads after a rain. After over two years' life on land, it again returns to the water, becomes green with red spots (as seen in the Figure), and

is able to reproduce its kind. Some salamanders never have lungs, but breathe through the moist skin.

Still other amphibians are the mud puppies, sirens or mud eels, and the axolotl. All of the amphibians differ from the reptiles in having a smooth skin with no scales, and in passing the early stage of their existence in the water.



Spotted salamander. From photograph loaned by the American Museum of Natural History.

**Characteristics of Amphibia.** — The frog belongs to the class of vertebrates known as *Amphibia*. As the name indicates (*amphi*, both, and *bia*, life), members of this group pass more or less of their life in the water, although in the adult state they are provided with lungs and can live on land. In the earlier stages of their development they take oxygen into the blood by means of gills. At all times, but especially during the winter, the skin serves as a breathing organ. The skin is soft and unprotected by bony plates or scales. The heart has three chambers: two auricles and one ventricle. Amphibians undergo metamorphosis during development.

Order I. *Urode'la.* Amphibia having usually poorly developed appendages. Tail persistent through life. Examples: mud puppy, newt, salamander.

Order II. *Anu'ra.* Tailless Amphibia. Hind legs well developed. Examples: toad and frog.

**Summary.** — The frog is one of the most common of our amphibians and shows the characteristics of this group: (1) it passes part of its life in the water as a tadpole and part either in or out of the water in the adult state, (2) the skin is soft and provided with slime glands, (3) the animal breathes as an adult by means of lungs and skin but in the young stage by means of gills, (4) it passes through a metamorphosis characteristic of the group.

The group are of some economic importance in the destruction of harmful insects (toad) and as food (frog).

**Problem Questions.** — 1. How does a frog breathe? catch food? jump? swim?

2. Explain the steps in the metamorphosis of a frog and the adaptations of each step.

3. How do the toads show amphibian characteristics?

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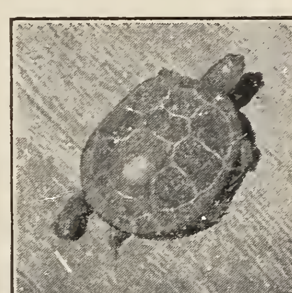
## Reptiles

Reptiles differ from amphibians in that they always breathe by means of lungs.

**Turtles' Adaptations for Life.** — The turtles form a large and interesting group, including both sea and land animals, the latter called tortoises. The body is flattened, and is covered on the dorsal and ventral sides by a bony framework. This covering is composed of plates cemented to the true bone underneath, the whole forming one big horny cover. This shell, an adaptation for protection, is remarkable in the box tortoise, where a hinge on the ventral side allows the animal to retreat within the shell, the head and legs being completely covered.



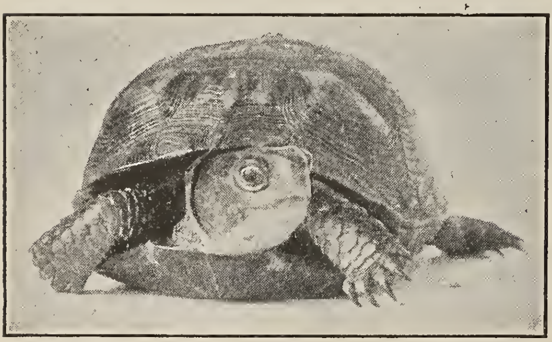
Western painted turtle.

**Adaptations for Food Getting.** — The long neck and powerful, horny jaws are factors in procuring food. Turtles have no teeth. Prey is seized and held by the jaws, the claws of the front legs being used to tear the food.

Turtles are very strong for their size. The stout legs carry the

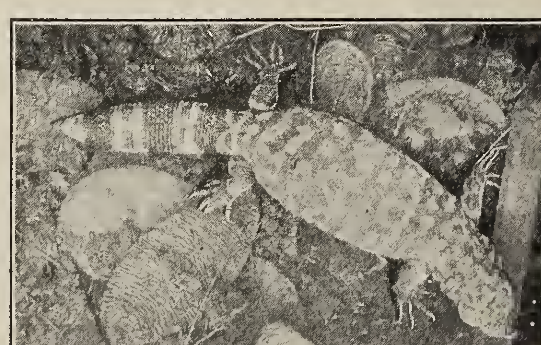
animal slowly on land, and in the water, being slightly webbed, they are of service in swimming. In some water turtles the front limbs are modified into flippers for swimming. The strong claws are used for digging, especially at the egg-laying season, for some turtles dig holes in sandy beaches in which the eggs are deposited.

**Some Different Turtles.** — Turtles are mostly aquatic in habit. Among the exceptions are the box tortoise already mentioned and the giant tortoise of the Galapagos Islands. Many of the salt-water turtles are of large size, the leatherback and the green turtle often weighing six hundred to seven hundred pounds each. The flesh of the green turtle and especially the diamond-back terrapin, an animal found in the salt marshes along our southeastern coast, is highly esteemed as food. Unfortunately for the preservation of the species, these animals are usually taken during the breeding season when they go to sandy beaches to lay their eggs.



Box tortoise. From photograph loaned by the American Museum of Natural History.

**Lizards.** — Lizards may be recognized by their long body with four legs of nearly equal size. The body is covered with scales. The animal never lives in water, it is active in habit, and it does not undergo a metamorphosis. Lizards are generally harmless creatures, the Gila monster of New Mexico and Arizona, a poisonous variety, being one exception. Lizards are of economic importance to man, because they eat insects and include the injurious ones in their dietary. The iguana of Central America and South



The Gila monster. Photograph one tenth natural size, by Davison.

America, growing to a length of three feet or more, has the distinction of being one of the few edible lizards.

**Snakes.** — Probably the most disliked and feared of all animals are the snakes. This feeling, however, is rarely deserved, for, on the whole, our common snakes are beneficial to man. The black snake and the milk snake feed largely on injurious rodents (rats, mice, etc.), the pretty green snake eats injurious insects, and the little DeKays snake feeds partially on slugs. If it were not that the rattlesnake and the copperhead are venomous, they also could be said to be useful, for they live on English sparrows, rats, mice, moles, and rabbits.


A garter snake, one of our commonest harmless reptiles.

Snakes are almost the only vertebrates without appendages. Although the limbs are absent, the pelvic and pectoral girdles are developed. The very long backbone is made up of a large number of vertebræ, as many as four hundred being found in the boa constrictor. Ribs are attached to all the vertebræ in the region of the body cavity.

**Locomotion.** — Locomotion is performed by pulling and pushing the body along the ground, a leverage being obtained by means of the broad, flat scales, or *scutes*, with which the ventral side of the body is covered. Snakes may move without twisting the body. This is accomplished by a regular drawing forward of the scutes and then pushing them backward rather violently.

**Feeding Habits.** — The bones of the jaw are very loosely joined together. Thus the mouth of the snake is capable of wide distention. It holds its prey by means of incurved teeth, two of which (in the poisonous snakes) are hollow or grooved, and serve as a duct for the passage of poison. The poison glands are at the base of the curved fangs in the upper jaw. The tongue is very long and cleft at the end. It is an organ

of touch and taste, and is not, as many people believe, used as a sting. The food is swallowed whole, and pushed down by rhythmic contractions of the muscles surrounding the gullet. Snakes usually refuse other than living prey.

**Adaptations.** — Snakes are not extremely prolific animals, but hold their own with other forms of life, because of their numerous adaptations for protection, their noiseless movement, protective color, and, in some cases, by their odor and poison.

Skull of boa constrictor, two thirds natural size. Note the in-pointing teeth. Photograph by Davison.

**Poisonous Snakes.** — Not all snakes can be said to be harmless. The bite of the rattlesnake of our own country, although dangerous, seldom kills. The dreaded cobra of India has a record of over two hundred and fifty thousand persons killed in thirty-five years. The Indian government yearly pays out large sums for the extermination of venomous snakes, over two hundred thousand of which have been killed during a single year.

**Alligators and Crocodiles.** — Crocodiles are mostly confined to Asia and Africa, while alligators are natives of North and South America.

Young alligator. One fifth natural size.

The chief structural difference between them is that the teeth in alligators are set in long sockets, while those of the crocodiles are not. Both of these lizardlike animals have broad, vertically flattened tails adapted to swimming. The eyes and tip of the snout, the latter holding the nostril holes, protrude from the head, so that the animal may float motion-

less near the surface of the water with only eyes and nostrils visible. The nostrils are closed by a valve when the animal is under water. These reptiles feed on fishes, but often attack large animals, as horses, cows, and even man. They seek their prey chiefly at night, and spend the day basking in the sun. The crocodiles of the Ganges River in India levy a yearly tribute of many hundred lives from the natives.

### Classification of Reptiles

Order I. *Chelo'nia* (turtles). Flattened reptiles with body inclosed in bony case. No teeth or sternum (breastbone). Two pairs of limbs. Examples: snapping turtle, box tortoise.

Order II. *Lacertil'ia* (lizards). Body covered with scales, usually having two pairs of limbs. Examples: fence lizard, horned toad.

Order III. *Ophid'ia* (snakes). Body elongated, covered with scales. No limbs present. Examples: garter snake, rattlesnake.

Order IV. *Crocodil'ia.* Fresh-water reptiles with elongated body and bony scales on skin. Two pairs of limbs. Examples alligator, crocodile.

**Summary.** — Turtles, lizards, and snakes belong to the class of vertebrates known as *Reptil'ia.* Such animals are characterized by having scales developed from the skin, which in the turtle have become bony and are connected with the internal skeleton, forming a shell. Reptiles always breathe by means of lungs, differing in this respect from the amphibians. They show their distant relationship to birds in that their large eggs are incased in a leathery, limy shell.

In general reptiles are useful either as food (turtles) or as destroyers of harmful animals. Most snakes are useful, although the poisonous snakes and crocodiles still take a yearly toll of deaths in some parts of the world.

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## Birds

**Problem.** *To study some adaptations in birds.* (*Laboratory Manual, Prob. XXXIX; Laboratory Problems: Prob. 118.*)

**Adaptations for Life.** — Birds are distinguished from all other animals by their covering of feathers and by the peculiar modification of the fore limb into a wing for flight. Hollow bones, feathers, and air spaces inside of the body cavity make them light for staying up in the air. The body is boat-shaped and pointed at the anterior end. The tail acts as a rudder. The

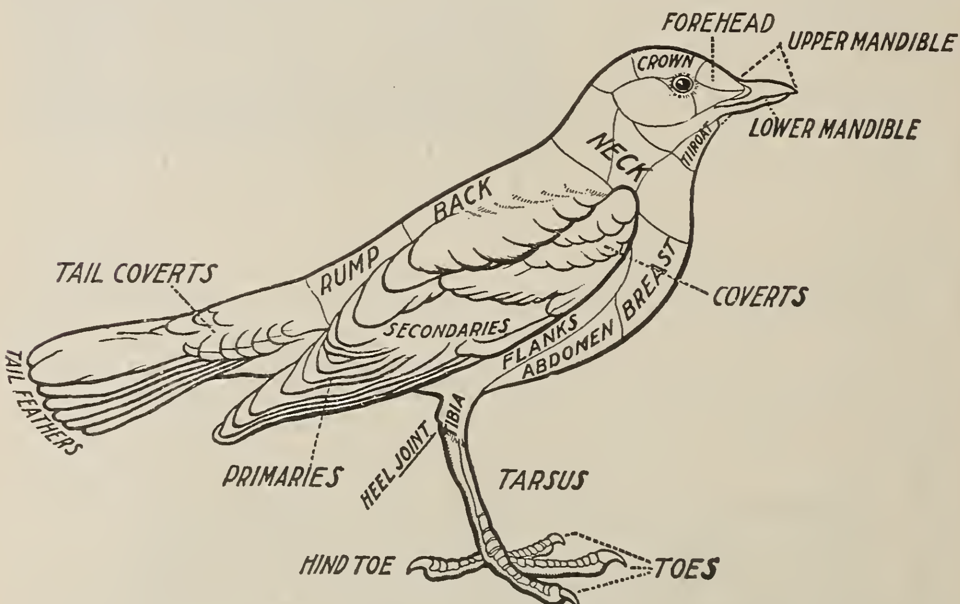



Diagram of a bird.

bill is horny and adapted for securing food. The legs show great variations for running, perching, swimming, and scratching.

**Field Work.** — Bird activities may best be studied out of doors. A city park offers more or less opportunity for such study, for several of our native birds make the parks their home. If not these, then the English sparrow can be studied as it is found everywhere in the East. The best time for making observations is early in the morning, especially in the spring season.

**Adaptation of the Wing.** — The wing is a modified arm, with the fingers very much reduced. It consists of a few long bones

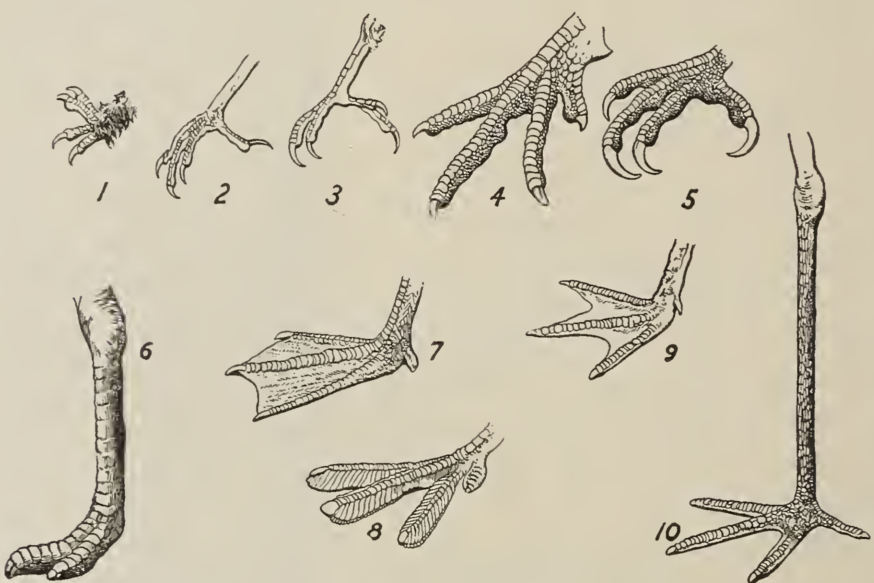
and a few small muscles, covered with skin. To the posterior edge of the wing are fastened long quill feathers which overlap and make a broad, stiff surface for pressing against the air. The wing is jointed and moves up and down in flight. Powerful breast muscles are attached to the wing bones and give great strength in movement. The wings fold against the side of the body when at rest. Watch a bird in flight. The rate of movement of the wing differs greatly in different birds. The wing of a bird is slightly concave on the lower surface when outstretched. Thus on the downward stroke of the wing more resistance is offered to the air. Birds with long, thin wings, as the hawks and gulls, move their wings in flight with much less rapidity than those with short, wide wings, as the grouse or quail. The latter birds start with much less apparent effort than the birds with longer wings; they are, however, less capable of sustained flight.

Feathers of a meadow lark. Which of the above are used for flight? How do you know? From photograph loaned by the American Museum of Natural History.

**Feathers.** — Few people realize that the body of a bird is not completely covered with feathers. Featherless areas can be found on the body of any common bird, although tiny "pin feathers" are found on such areas as well as on other parts of the body. Soft down feathers on the body make a covering for warmth. Larger feathers give the rounded contour to the body. In the wings we find quill feathers; these are adapted for service in flight by having long hollow shafts, from which lateral interlocking branches are given off, the whole making a light structure and offering considerable resistance to the air. Feathers are developed from the

outer layer of the skin, and are formed in almost exactly the same manner as are the scales of a fish or a lizard. The first feathers developed on the body are evidently for protection against cold and wet, but later in life they serve other uses as well. The feathers of most male birds are brightly colored. This seems to make them attractive to the females of the species; thus the male may win its mate.

**Adaptations of the Legs.** — The ankle of a bird is long and reptile-like and is covered, like the foot, with scales. The most extraordinary adaptations are found in the feet of various birds



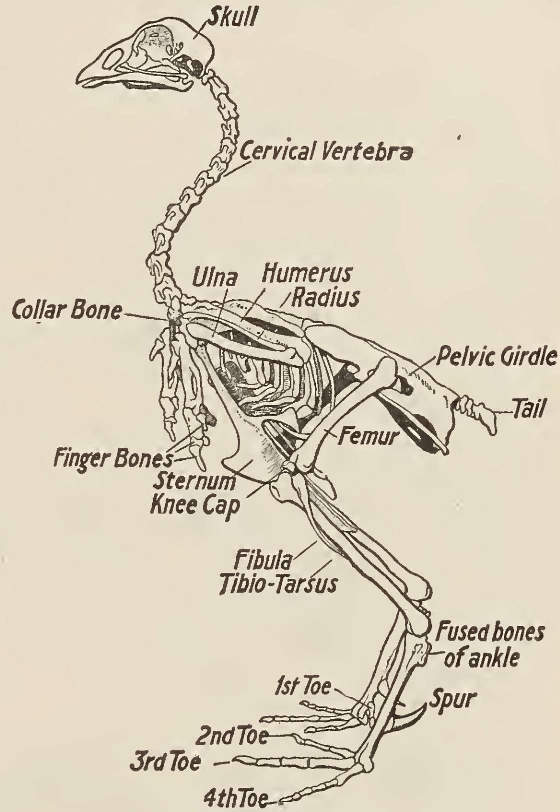

Adaptation in feet of birds: 1, swift (clinging); 2, ouzel (perching); 3, woodpecker (climbing); 4, pheasant (scratching); 5, hawk (seizing prey); 6, ostrich (running); 7, duck (swimming); 8, grebe (diving); 9, avocet (wading); 10, stork (wading). In each case can you make out the way in which the bird's foot is adapted to do its work?

some for perching, others for swimming, others for wading, etc. We are able, by looking at the feet of a bird, to decide almost certainly its habitat, method of life, and perhaps its food.

In the perching birds we find three toes in front and one behind, the hind toe playing an important part in clinging to the perch. In swallows, rapid and untiring flyers, the feet are small. In the case of the parrots, where the foot is used for holding food, climbing, and clinging, we find the four-clawed toes arranged

two in front and two behind. Hawks and eagles are provided with strong curved talons with which the prey is seized and killed.

Adaptation for semiaquatic life is seen in plovers, herons, or storks, where long legs and long toes enable the birds to seek their food in soft mud among reeds or lily pads, or along sand flats. True aquatic birds, on the other hand, are provided with webbed toes. The foot of the common barnyard duck, for example, is much like that of the alligator. In the ostrich and cassowary the wings are small and not used for flight; the legs are long and powerful and fitted for rapid running.



Skeleton of a fowl.

**Perching.** — The method of perching is an interesting one. The three toes in front curve around the perch, often meeting the posterior toe, which is curved also. The tendons of the leg and foot are self locking, and such birds are held in place as perfectly when asleep as when awake. A part of the ear, known as the *semicircular canals*, has to do with the function of balancing. In the flamingoes and other birds, which do not perch, balancing appears to be automatic; thus the bird is able to maintain an upright position even when asleep.

**Tail.** — The tail is sometimes used in balancing; its chief function, however, appears to be that of a rudder during flight. Most birds have under the skin of the tail a large oil gland, whence comes the supply of oil that is used in waterproofing the feathers when they preen themselves.

**The Skeleton.** — The skeleton combines lightness, flexibility,

and strength. Many bones are hollow or have large spongy cavities. The bones of the head and neck show many and varied adaptations to the life the bird leads. The vertebræ which form the framework of the neck are strong and flexible. They vary in shape and in number. The swan, seeking its food under water, has a neck containing twenty-three long vertebræ; the English sparrow, in a different environment, has only fourteen short ones. Some bones, notably the breastbone, are greatly developed in flying birds for the attachment of the muscles used in flight.


Adaptations in the bills of birds. Could we tell anything about the food of a bird from its bill? Do these birds get their food in the same manner? 1, shoebill; 2, hawk; 3, bunting; 4, thrush; 5, flamingo; 6, spoonbill; 7, pelican; 8, duck; 9, pigeon; 10, toucan; 11, bird of paradise; 12, swift; 13, skimmer; 14, stork.

**Bill.** — The form of the bill shows adaptation to a wonderful degree, varying greatly according to the habits of the bird. A duck has a flat bill for pushing through the mud and straining out the food; a bird of prey has a curved or hooked beak for tearing; the woodpecker has a sharp, straight bill for piercing the bark of trees in search of the insect larvæ underneath.

Birds do not have teeth. The edge of the bill may appear to be toothed, as in some fish-eating ducks; however, the projections are not true teeth. Frequently the tongue has sharp,

toothlike edges which serve the same purpose as the recurved teeth of the frog or snake.

**Adaptations for Active Life.** — The rate of respiration, of heartbeat, and the body temperature are all higher in the bird than in man.

These are among the greatest adaptations to the active life led by a bird. Man breathes sixteen or eighteen times a minute. Birds breathe from twenty to sixty times a minute. The lungs of a bird are not large. Its bronchial tubes are continued through the lungs into hollow spaces filled with air, which are found between the organs of the body. Only the lungs, however, are used for breathing. Because of the increased activity of a bird, there comes a necessity for a greater supply of oxygen, an increased blood supply to carry the material to be oxidized in the release of energy, and a means of rapid excretion of the wastes resulting from the process of oxidation. A bird may be compared to a high-pressure steam engine; in order to release the energy which it uses in flight, a large quantity of fuel which will oxidize quickly must be used. Birds are large eaters, and the digestive tract is fitted to digest the food quickly. As soon as the food is absorbed by the blood, it may be sent rapidly to the places where it is needed, by means of the strong four-chambered heart and large blood vessels.

The high temperature of the bird is a direct result of this rapid oxidation; furthermore, the feathers and the oily skin form an insulation which does not readily permit the escape of heat. This insulating cover is of much use to the bird in its flights at high altitudes, where the temperature is often very low.

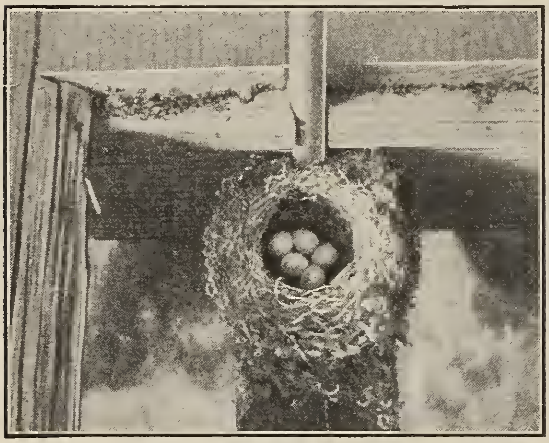
**The Nervous System and the Senses.** — The central nervous system is well developed. A large forebrain is present, which, according to a series of elaborate experiments with pigeons, is found to have to do with the conscious life of the bird. The cerebellum takes care of the acts which are purely mechanical.

Sight is probably the best developed of the senses of a bird. The keenness of vision of a hawk is proverbial. It has been noticed that in a bird which hunts its prey at night, the eyes look toward the front of the face. In a bird which is hunted, as in the dove, the eyes are placed at the sides of the head. In the case of the woodcock, which feeds at night in the

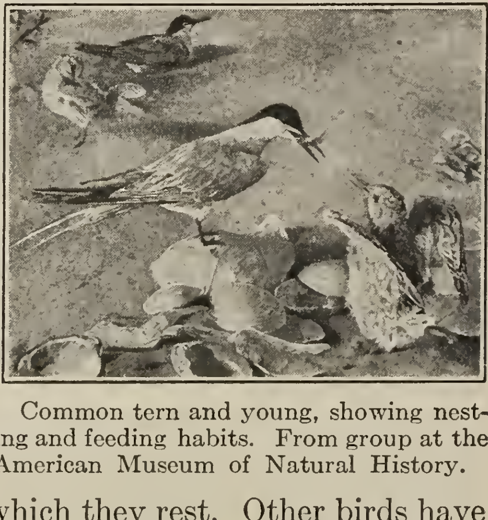
marshes, and which is in constant danger from attacks by owls, the eyes have come to lie far back on the top of the head. Hearing is also well developed in most birds, as may be demonstrated with any canary.

The sense of smell does not appear to be well developed in any bird, and is especially deficient in seed-eating birds.

**Nesting Habits.** — Among the most interesting of all instincts shown by birds are those of nest building. Some invertebrates, as spiders and ants, protect the eggs when laid. In the vertebrate group some fishes (as the sunfish and stickleback) make nests for holding the eggs. But most fishes, and indeed nearly all other vertebrates lower than the birds, leave the eggs to be hatched by the heat of the sun. Birds incubate their eggs, that is, hatch them, by the heat of their bodies. Hence a nest, in which to rest, is needed. The ostrich is an exception; it makes no nest, but lays its eggs on the ground; then the male and the female take turns in sitting on them. Such birds as are immune from the attacks of enemies because of their isolation or their protective coloration (as the puffins, gulls, and terns), build a rough nest among the rocks or on the beach. The eggs, especially those of the tern, are marked and colored so as to be almost indistinguishable from the rocks or sand on which they rest. Other birds have made their nest a home and a place of refuge as well as a place



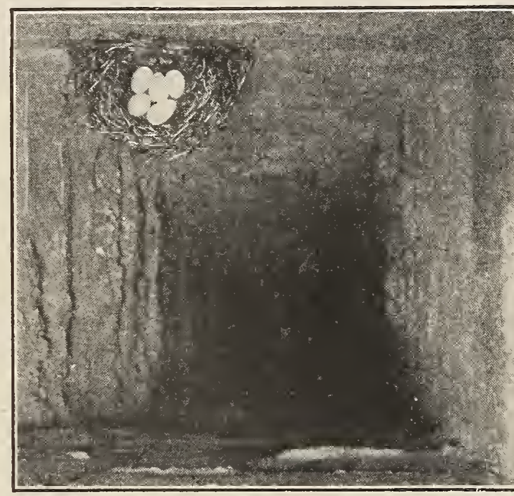
Nest of a phœbe under a barn floor.



Common tern and young, showing nesting and feeding habits. From group at the American Museum of Natural History.

to hatch the eggs. Such are the nest of the woodpecker in a hollow tree and the hanging nest of the oriole. Some nests which might be easily seen because of their location are often rendered inconspicuous by the builders; for example, the lichen-covered nest of the humming birds.

**Care of the Young.** — After the eggs have been hatched, the young in most cases are quite dependent upon the parents for food. Most young birds are prodigious eaters; as a result they grow very rapidly. It has been estimated that a young robin eats two or three times its own weight in worms every day. Many other young birds, especially kingbirds, are rapacious insect eaters. In the case of the pigeons and some other birds, food is swallowed by the mother, partially digested in the crop, and then regurgitated into the mouths of the young nestlings.



Nest of the chimney swift.

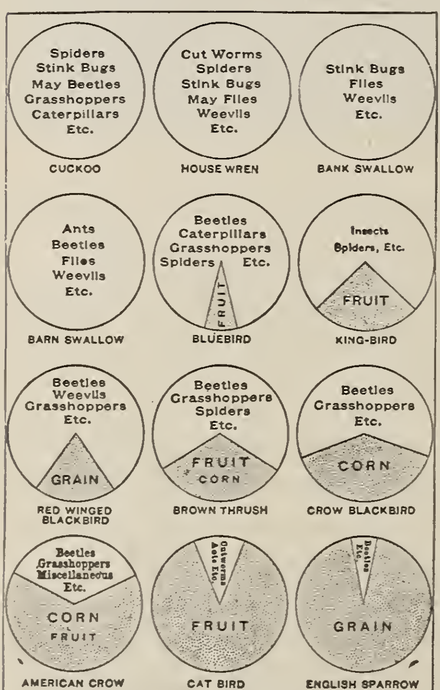
***Problem.*** *How birds are of economic importance.* (*Laboratory Manual, Prob. XL; Laboratory Problems, Probs. 121, 122.*)

**Geographical Distribution and Migrations.** — Most of us are aware that some birds remain in a given region during the whole year, while other birds appear with the approach of spring, and depart southward with the warm weather in the fall of the year. Such birds we call *migrants*, while those that remain in one place the year round are called *residents*.

In Europe, where the problem of bird migration has been studied carefully, migrations appear to take place along well-defined paths. These paths usually follow the coast very exactly, although in places they may take the line of coast that existed in former geological times. In this country the Mississippi valley, a former arm of the sea, forms one line of migration, while the north Atlantic seacoast forms another route.

It has been shown that the southern movement of migratory birds in the fall of the year is not due entirely to the advent of cold weather, but is largely a matter of adjustment to food supply. A migrant almost always depends upon insects, fruits, and grains for the whole or a large part of its food. Most winter residents, as the crow, are omnivorous in diet. Others, as the English sparrow, may be seed eaters, but under stress change their diet to almost anything in the line of food; still others, as the woodpeckers, although insect-eating birds, manage to find the desired food tucked away under the bark of trees. Many insect-eating birds, however, because their food is found on green plants, appear to be forced southward by the cold weather.

**Food of Birds.** — Birds are of tremendous economic importance to our country and a very great help to agriculture because a large part of their diet includes insects harmful to vegetation, and the seeds of weeds, enemies also of the farmer. Birds like the crow and robin feed at times upon fruit and grain and at other times upon insects. So grateful were the early settlers in Utah to the seagulls for delivering them from a plague of "crickets" (perhaps locusts), that they erected a beautiful monument to the seagulls. A plague of insects threatened to destroy the crops and the people were in despair, when along came crowds of seagulls that ate the pests and saved the crops.




Food of some common birds.

Not all birds are seed or insect feeders. Some, as the cormorants, ospreys, and terns, are active fishers. Near large cities gulls act as scavengers, destroying much floating garbage that otherwise might be washed ashore to become a menace to

health. Sea birds also live upon shellfish and crustaceans (as small crabs, shrimps, etc.); some even eat lower organisms. The kea parrot, once a fruit eater, now takes its meal from the muscles forming the backs of living sheep. Birds of prey (owls and hawks) eat smaller birds and mammals, including many rodents; for example, field mice, rats, and other pests.

**Common Birds.** — The following pages will help one to recognize a few of our common birds which are of decided economic value or harm. The size, color markings, food, and familiar habits of some of our common birds will be given, with a brief statement of the reason why they are man's friends or enemies.

**Robin.** — A bird known to all of us makes an excellent type for comparison with other less known birds. The robin is 9 to 10 inches long. The male is dark gray above tinged with olive, brown on the wings, and black on the head and tail; the throat is light gray with black spots, and the breast is red. The female is similar but darker in color. The robins live near houses and in orchards and make their nests of grass and mud, in trees or on buildings. The robin is a true thrush, whose pleasing song delights us in early Spring. Its economic position is often discussed as it eats much fruit early in the season. Ordinarily its diet consists of about 40 per cent insects, most of which, as ground beetles, caterpillars, plant lice, and cutworms, are harmful. It eats earthworms, also, which are useful to the farmer.

Bluebird.

**Bluebird.** — One of our earliest migrants. Its cheery note and blue coat are easily recognized. It is $6\frac{1}{2}$ to 7 inches in length. The male is bright blue above, and chestnut underneath. The female is duller in color. It nests in holes in trees or posts and in bird houses. Its food consists largely of grasshoppers with a few beetles, spiders, and caterpillars.

**Song sparrow.** — Another of our earliest visitors. The male is about $6\frac{1}{2}$ inches long, brown above, head reddish-brown mottled with blackish streaks. A streak of gray runs through

the center of the crown, and there is a characteristic black line through the eye and two on the throat. The breast is spotted on a white ground. Its nest is usually on the ground or in a bush. It is a friendly bird and is often seen near houses, though it prefers moist areas farther away from man. It eats some insects, but like most of the native sparrows it feeds mainly upon weed seeds.

**Chickadee.** — A smaller bird, about $5\frac{1}{4}$ inches in length. It is often an all-year-round resident. The crown of the head and throat are black, the cheeks white, the back gray, and the belly often a dirty white. It feeds upon spiders, plant lice, and other insects, and in the winter time devours large quantities of eggs laid by these pests, one bird eating more than 430 eggs in a single day. It is certainly one of man's best bird friends.

**House Wren.** — This little migrant nests around our homes, is a great songster and a decided asset to us, because of its varied diet of cutworms, spiders, weevils, May flies, etc. It has been estimated to catch 600 insects a day. It is a friendly little bird whose worst enemies are English sparrows and cats. A proper nesting box with a small entrance is one of its best means of protection. The house wren is not quite 5 inches long. The upper part is brown, the lower grayish brown and white. The wings, flanks, and tail are slightly barred. It can be recognized easily by its small size, coloring, incessant singing or chattering, and by the fact that its tail is frequently held erect when at rest.

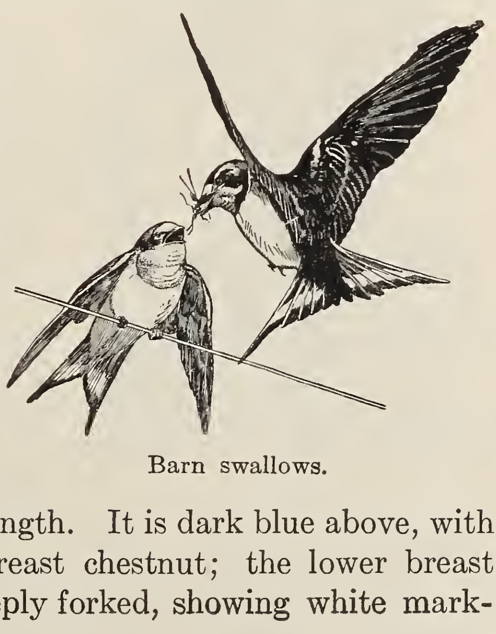
American goldfinch.

**American Goldfinch.** — This bright yellow songster is one of our most attractive birds. It is often called the wild canary. It is a little over 5 inches long. The male has a bright yellow body with a black cap and black markings on tail and wings. The female is a deep brown. The goldfinch eats seeds of weeds, preferring those of the dandelion and thistle, two of our greatest weed pests.

**Yellow Warbler.** — A bird often confused with the goldfinch is the yellow warbler. Like all warblers, this is a small bird; it is about 5 inches in length. Its color is yellow, flecked with olive or brown (note it has *no* black on the head as does the goldfinch). It nests near houses in low trees or bushes. It is of much economic importance because of its preference for the browntail and gypsy moth caterpillars, and other enemies of the forest trees. We are spending millions of dollars every year to fight these imported pests, and the goldfinch may help turn the scale against them if it is protected and encouraged to nest near our homes. What can you do to help?

**Phœbe.** — Another tireless hunter of insect pests is the phœbe. This bird is a flycatcher, seizing insects on the wing. It builds a nest of mud — often under old bridges, around barns, or sometimes under a barn floor (p. 292). Its food consists of browntail and gypsy moths, cankerworms, beetles, and flies. The phœbe is about 7 inches long, dusky olive-brown above, yellowish white underneath, wings and tail dusky. The head is slightly crested, bill and feet are black. It is one of our early visitors.

**Barn Swallow.** — Another bird with nesting habits similar to those of the phœbe is the barn swallow, which makes a nest plastered to the rafters of a barn or outbuilding. While most birds decrease in number with the cutting of forests and the building of cities, the barn swallow has increased because it feeds on insects which live on crops in cleared fields. It eats moths of cutworms, codling moths, and leaf cutters, with many others of the farmer's insect enemies. This swallow is between 6 and 7 inches in length. It is dark blue above, with forehead, throat, and upper breast chestnut; the lower breast and belly buff. The tail is deeply forked, showing white markings when spread.



Barn swallows.

**Catbird.** — Another bird which nests near houses and prefers the company of man is the catbird. From early May to late October its various calls and songs are the delight of all bird lovers, for it is a great mimic and somewhat of a tease. The catbird, although it eats much fruit, is largely an insect feeder and gives its young 95 per cent insect food. It is an enemy to caterpillars, especially the cutworm. It is about 9 inches in length, and of a dark grayish color, with the top of head and the tail blackish.

**Downy Woodpecker.** — The woodpeckers are familiar to most boys and girls because of their conspicuous color and their peculiar habits. The downy woodpecker is 6½ inches long, black and white barred, with a small patch of scarlet at the top of the head. It runs quickly up and down the trunks of trees, tapping the wood to locate insect holes. The bill is strong, sharp at the end, and is used as a chisel in boring into wood. The tongue is spearlike, 1 to 1½ inches long, and is used to pull out the larvæ which it seeks. Its chief food is larvæ of maple, birch, apple and other borers. Woolly aphids, caterpillars, and crysalids are also its prey. A woodpecker has been observed to work over 180 trees in 2½ hours' time. In some cases a downy woodpecker is found which lives up to its name of sapsucker, but the good done by these little birds far outweighs the harm done by them.

Flicker.

**Flicker.** — This bird is not a typical woodpecker although it has similar habits. It is a large bird 12 inches long. The male is brown above and golden yellow below, with black markings, and a scarlet crescent across the neck. It has a white rump which is conspicuous in flight and makes an easily recognized mark. The flicker is generally useful, feeding upon plant lice, ants (which

make up about 45 per cent of its food), grasshoppers, caterpillars, and weed seeds. Like the woodpecker, it nests in hollow trees.

**Baltimore Oriole.** — This bright-colored and attractive bird is about 7½ inches long. The male has the upper back and throat black with the outer tail feathers, breast, and under parts orange. The female is not so brilliantly colored, having a yellow instead of orange color. The hanging nests of the oriole, often woven with bits of string and other materials, are a common sight in elm trees near our homes. These birds prefer inhabited areas and, because of their protected nests, are on the increase in spite of cats and the English sparrow. They feed largely upon the cankerworm, tussock, browntail, and forest tent caterpillars.

**Screech Owl.** — This is a small owl and one of the most useful, as it feeds upon field mice and other small destructive rodents as well as upon some moths, caterpillars, and beetles. It is about as large as a quail, or 9½ inches in length. Its general coloring is gray on the under parts and reddish brown above. The eye is yellow. It usually nests in hollow trees.


Screech owl.

**Crow.** — Our common crow, a glossy black bird from 16 to 17½ inches long, is one of the few birds that may do more harm than good. In the early spring the crow is useful and eats insect larvæ, such as cutworms and May beetle larvæ, and field mice, but later it does much harm in the newly planted corn fields. The crow is accused of stealing young chickens, ducks, and turkeys, and the eggs and young of many useful birds.

**English Sparrow.** — The English sparrow is an example of a bird introduced for the purpose of insect destruction, that has done great harm because of its relation to our native birds. Introduced at Brooklyn in 1850 for the purpose of exterminating the cankerworm, it soon abandoned an insect diet to a large extent in favor of one of grain and has driven out many of our native insect feeders. Investigations by the Department of

Agriculture show that in the country these birds and their young feed to a large extent upon grain, thus showing them to be injurious to agriculture. Dirty and very prolific, they long since worked their way from the East as far as the Pacific coast. In this area the bluebird, song sparrow, and yellowbird have all been forced to give way, as well as many larger birds of great economic value and beauty. The English sparrow has become a national pest, and should be exterminated in order to save our native birds. It is feared in some quarters that the English starling, which has recently been introduced into this country, may in time prove a pest as formidable as the English sparrow.


Cooper's hawk.

**Birds Harmful to Man.** — While there are a few birds that do both harm and good like the crow and the robin, there are others that are bad and we can find little or no good to say about them. The English sparrow is the greatest bird pest, for reasons given above. The cowbird never builds a nest nor cares for her young. She lays her eggs in the nests of smaller birds, where later the young cowbirds cause the death of the rightful inhabitants of the nest. Cooper's hawk, the sharp-shinned hawk, and the great horned owl kill smaller, beneficial birds. The beautiful belted kingfisher sits in a tree beside the rivers and fishes, eating aquatic insects, mice, frogs, and grasshoppers also. Fortunately there are very few birds to put on the black list.

**Extermination of our Native Birds.** — Within recent times has been witnessed the almost total extermination of some species of our native birds. The American passenger pigeon, once very abundant in the Middle West, is now practically extinct. To-day not a single specimen of this pigeon can be found, because they were slaughtered by the hundreds of thousands during the breeding season. The wholesale killing of the snowy egret to furnish ornaments for ladies' headwear is another example of the improvidence of our fellow countrymen. The English sparrow and wholesale killing of birds for plumage, eggs, and food,

and often for mere sport, caused the decrease of our birds to 46 per cent in thirty states and territories within fifteen years. Laws made by state and national governments have done much to protect the birds and check their rapid decrease. Places of refuge or sanctuaries where birds are undisturbed during the nesting season have saved the lives of many hundreds. Societies and clubs have aroused interest all over the country and now many boys and girls as well as older people are watching, feeding, and protecting birds in every possible way. The effect of killing native birds is now seen in Italy and Japan, where insect pests are increasing. We should all do our part in preventing the loss of our native birds here, not only because of their beauty and their song, but also because of their very great economic importance.

**Relationship of Birds and Reptiles.** — The birds afford an interesting example of how the history of past ages of the earth has given a clue to the structural relation which birds bear to other animals. Several years ago, two fossil skeletons were found in Europe of a birdlike creature which had not only wings and feathers, but also teeth and a lizardlike tail. From these fossil remains and certain structures (as scales) and habits (as the egg-laying habits), naturalists have concluded that birds and reptiles in distant times were nearly related and that our existing birds probably developed from a reptile-like ancestor many ages ago.

### Classification of Birds

Division I. *Rati'tæ.* Running birds without keeled breastbone. Examples: ostrich, cassowary.

Division II. *Carina'tæ.* Birds with keeled breastbone.

- Order i. *Pas'seres.* Perching birds; three toes in front, one behind. One half of all species of birds are included in this order. Examples: sparrow, thrush, swallow.
- Order ii. *Galli'næ.* Strong legs; feet adapted to perching. Beak stout. Examples: jungle fowl, grouse, quail, domestic fowl.
- Order iii. *Rapto'res.* Birds of prey with hooked beak and strong claws. Examples: eagle, hawk, owl.
- Order iv. *Grallato'res.* Waders. Long neck, beak, and legs. Shore and water-loving birds. Examples: snipe, crane, heron.
- Order v. *Natato'res.* Divers and swimmers. Legs short, toes webbed. Examples: gull, duck, albatross.

ORDER VI. *Colum'bæ.* Like Gallinæ, but with weaker legs. Examples: dove, pigeon.

ORDER VII. *Pica'riæ.* Woodpeckers. Two toes point forward, two backward, an adaptation for climbing. Long, strong bill. Examples: Downy and hairy woodpeckers.

**Summary.** — Birds are feathered vertebrates with the anterior appendages fitted for flying. Adaptations for food getting are numerous and well shown in the different types of beaks and claws.

Our native birds are of great economic importance because of their feeding habits, as follows: (1) They eat insects which destroy crops, injure trees, and are pests in many ways; examples, the house wren, phoebe, and downy woodpecker. (2) They eat seeds of weeds, which if allowed to grow would give the farmer much trouble; examples, sparrows, goldfinch, and pigeon. (3) They kill harmful rodents, as field mice and moles; example, screech owl. (4) They act as scavengers; example, the herring gull.

Only a few birds are harmful, as indicated below: (1) They eat grain and fruit; examples, the crow and the robin. (2) They catch fish; example, the kingfisher. (3) They dig deep holes in trees and allow the sap to run out; example, the sapsucker. (4) They drive out and harm useful birds; examples, the English sparrow and some hawks.

As the benefit received from birds is tremendous and the harm is very slight, we should do all that we can to protect and encourage these feathered neighbors.

**Problem Questions.**—1. What are the characteristics of a bird?

2. Name some bird adaptations for food getting, for nest making, and for protection.

3. Discuss the food habits of ten useful birds found in your locality.

4. Name five birds that are of doubtful economic importance and give the reasons for your answer.

5. Classify each of the above-named birds according to the simple classification at the end of the section on birds.

6. Explain how the food of birds determines their migrations.

7. Why are birds considered related to reptiles?

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## Mammals

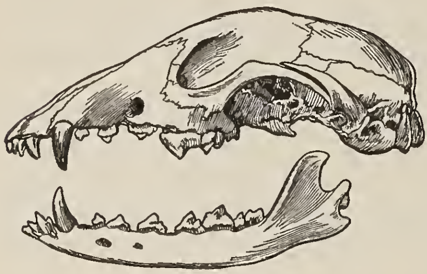
**Mammals.** — Dogs and cats, sheep and pigs, horses and cows, many other animals covered with hair, and man himself, have structural characteristics which cause them to be classed as *mammals.* Mammals, like some other vertebrates, have lungs and warm blood. Unlike all other vertebrates, however, they have a hairy covering and bear young developed to a form similar to their own,[1] which they nurse with milk secreted by glands known as the *mam'mary glands;* hence the term "mammals." Mammals are considered the highest of vertebrate animals, not only because of their complicated structure, but because of their mental development.

**Adaptations in Mammalia.** — Of the thirty-five hundred species of mammals, most inhabit continents; a few species are found only on islands; and some, as the whale, inhabit the ocean. They vary in size from the whale and the elephant to the tiny shrew mice and moles. Adaptations abound; the seal and whale have the limbs modified into flippers, the sloth and squirrel have limbs peculiarly adapted to climbing, while the bats have the fore limbs modeled for flight.

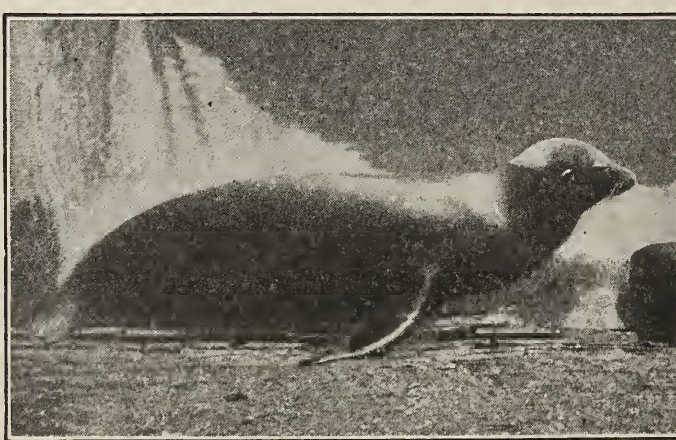
**Carnivora.** — As the word "carniv'ora" denotes, carnivorous mammals are to a large extent flesh eaters. In a wild state they hunt their prey, which is caught and torn with the aid of well-developed claws and long, sharp teeth. These teeth, so

[1] With the exception of the monotremes.

well developed in the dog, are known as *canine* teeth or dog teeth. All flesh-eating mammals are wandering hunters in a state of nature; many, as the bear and lion, have homes or dens to which they retreat. Some (for example, bears and raccoons) live part of the time upon berries and fruit. Seals, sea lions, whales, and walruses are adapted to a life in the water; and their hind limbs are almost useless on land. Some of the fur bearers, as the otter and mink, lead a partially aquatic life. Others in this great group prefer regions of comparative dryness, as the inhabitants of the South African belt. A few, like the raccoon, live most of their time in the trees. Many have adaptations for food getting and escape from enemies; the seasonal change in color of the weasel is an example of an adaptation which serves both of the above purposes. This is only one of hundreds that might be mentioned.



Skull of dog.

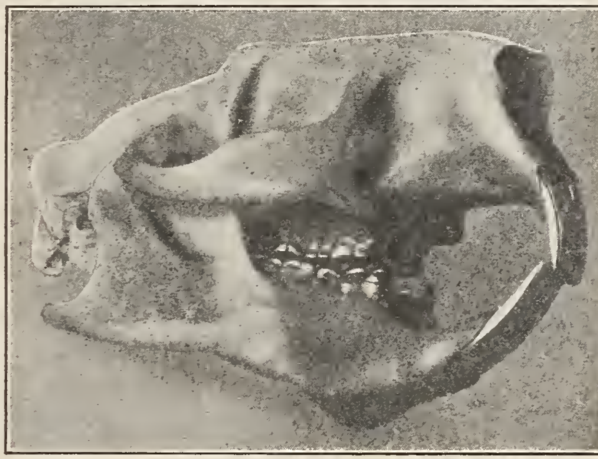


California sea lion. Photographed in the Philadelphia Zoölogical Gardens by Davison.

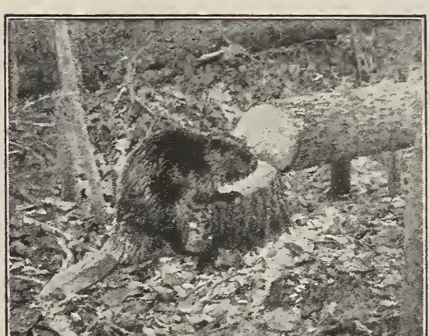
*Economic Importance.* — The Carnivora as a group are of much economic importance as the source of most of our fur. The fur seal fisheries alone amount to many millions of dollars annually. Otters, skunks, sables, weasels, and minks are of considerable importance as fur producers. Our domestic cats are

such factors in the extermination of our native birds that their place as house pets is seriously questioned by some people. Homeless cats are great hunters of birds and a general nuisance and should not be allowed to exist. In India, tigers, and in Africa, lions, are man-eating in certain localities, and in our own country wolves, pumas, and wild cats do some damage.

**Rodents.** — Mammals known as rodents have the teeth so modified that on both upper and lower jaws two prominent incisor teeth can be used for gnawing. These teeth keep their chisel-like edges because the back part of the teeth is softer and wears away more rapidly. The canine or dog teeth are lacking. We are all familiar with the destructive gnawing qualities of one of the commonest of all rodents, the rat. The common brown rat is an example of a mammal which has followed in man's footsteps all over the world, doing him harm. Starting from China, it spread to Europe, and in 1775 it had obtained a lodgment in this country. In seventy-five years it reached the Pacific coast, and is now fairly common all over the United States, being one of the most prolific of all mammals. It is estimated that the rat causes a property loss of at least $200,000,000 annually. A determined effort is being made to exterminate this pest because of its connection with bubonic plague.

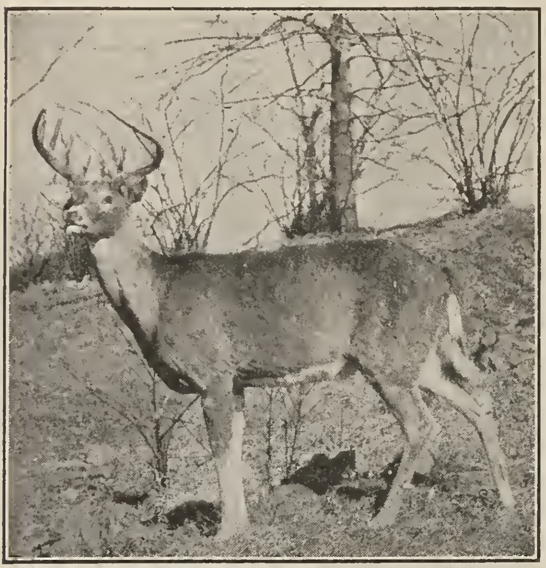


Skull of a porcupine, a rodent. Notice the large overlapping incisor teeth. Compare them with the teeth of a dog (see page 304).



Beaver. Copyright, 1900, by A. Radcliffe Dugmore.

Although most rodents may be considered as pests (as the rat and mouse) others are of use to man. Some of them furnish food, as the rabbits, hares, and squirrels. Rabbits, although rapid breeders, are kept in check in most parts of this country by their natural enemies, birds of prey and flesh-eating mammals. But in Australia, where they were introduced by man, they have become so numerous that the Government gives a bounty for their destruction. Thousands of sheep are starved to death each year because rabbits eat their pasturage. The fur of the beaver, one of the largest of this order, is of considerable value, as are the coats of several other rodents. The fur of the rabbit is used in the manufacture of felt hats. The quills of the porcupines (greatly developed and stiffened hairs) have a slight commercial value.



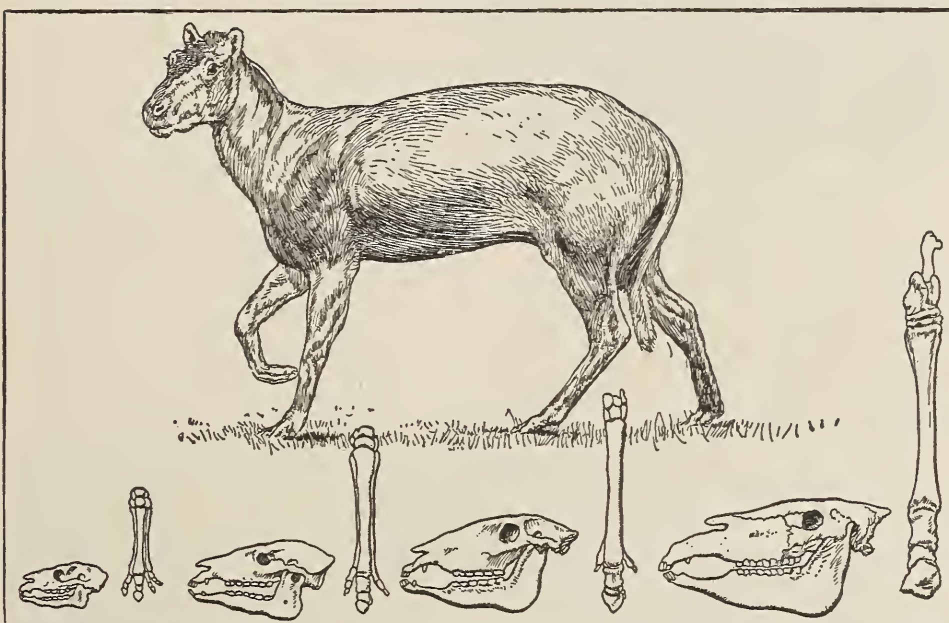
Virginia deer. From photograph loaned by the American Museum of Natural History.

**Ungulates: Hoofed Mammals.** — This group includes most of the domesticated animals, as the horse, cow, sheep, and pig. Many of this group of animals came under the subjugating influence of man and now they form an important part of the world's wealth.

The bison.

The order of ungulates is a very large one. It is characterized

by the fact that the nails have grown down and become thickened as hoofs. In some cases only two (the third and fourth) toes are largely developed. Such animals have a cleft hoof, as the ox, deer, sheep, and pigs. They are the even-toed ungulates. The deer family contains the largest number of species and individuals among our native forms, and in fact the world over. Among them are the common Virginia deer of the Eastern states, the white-tailed deer of our Adirondack forests. The bison, or buffalo, is nearly related to the deer and wild cattle. Formerly bisons existed in enormous numbers on our Western plains. They were often hunted by whites and Indians for the hides and tongues only, and thousands of carcasses were left to rot after a hunt. They are now almost extinct.



Evolution of the horse. The illustration is a scientist's sketch of the earliest horse, which became extinct many ages ago. It was about the size of a fox; the bones of its head and fore foot are shown at the left. The bones of the present horse's head and fore foot are shown at the right. Between are those of animals intermediate in the line of descent.

**Geologic History of the Horse.** — In some ungulates the middle toe of the foot has become largely developed, with the result that the animal stands on it. Among such animals are the zebra and the horse.

We have, from time to time, made reference to the fact that certain forms of life, now almost extinct, flourished on the earth in former geologic periods. It is interesting to note that America was the original home of the horse, although at the time of the earliest explorers the horse was unknown here. The wild horse of the Western plains descended from horses introduced by the Spaniards. Long ages ago, the remote ancestors of the horse were probably little animals the size of a fox, with five-toed feet. The earliest horse we have knowledge of had four toes on the fore and three toes on the hind feet. Thousands of years later there existed a larger horse, the size of a sheep, with three toes on each foot. By gradual changes, caused by the tendency of animals to vary, there was eventually produced our present horse, an animal with legs adapted for rapid locomotion, with feet particularly fitted for life in open fields, and with teeth which serve well to seize and grind herbage.

**Domestication of Animals; Breeding by Selection.** — The prehistoric horse for some reason disappeared in this country, but continued to exist in Europe, and man, emerging from his early savage condition, began to make use of the animal. We know the horse was domesticated in early Biblical times, and that it became one of man's most valued servants. In more recent times, superior horses have been developed by selective breeding.

To do this, the horses that have varied and show the characteristics desired by the breeder are selected and bred together. The young from these animals are likely to be like their parents and may be even more likely to show the characteristics the breeder desires. If this process is repeated for several generations, it will be seen that man, by *artificial selection*, may have considerably modified the type of horse with which he started. In this manner the various types of horses familiar to us as draft horses, coaches and hackneys, and the trotters have been established and improved. In a similar manner the various breeds of cattle, sheep, swine, and other domestic animals have been obtained.

It is needless to say that man has caused a tremendous change in animals by domesticating them and by selective

breeding. When we realize the very great amount of money invested in domesticated animals; and that there are over 50,000,000 each of sheep, cattle, and swine and over 20,000,000 horses owned in this country, we may see how important a part domestic animals play in our lives.

**Orders of Mammals.** — The lowest are the *monotremes*, animals which lay eggs like the birds, although they are provided with hairy covering like other mammals. Such are the Australian spiny anteater and the duck mole.

All other mammals give birth to young which are developed to a form similar to their own. The kangaroos and opossums, however, are provided with a pouch on the ventral side of the body in which the very immature, blind, and helpless young are nourished until they are able to care for themselves. These pouched animals are called *marsu′pials*.

Virginia opossum. Photograph, one eighth natural size, by N. F. Davis.

The other mammals, in which the young are born able to care for themselves, and have the form of the adult, may briefly be classified as follows:

ORDER I. *Edenta'ta.* Toothless or with very simple teeth. Examples: anteater, sloth, armadillo.

ORDER II. *Ceta′cea.* Adapted to marine life; teeth (of whales) sometimes platelike. Examples: whale, porpoise.

ORDER III. *Sire′nia.* Fishlike; pectoral limbs paddle-like; pelvis absent, no vertical dorsal fin. Examples: manatee, dugong.

ORDER IV. *Roden′tia.* Incisor teeth chisel-shaped, usually two above and two below. Examples: beaver, rat, porcupine, rabbit, squirrel.

ORDER V. *Ungula′ta.* Hoofs; teeth adapted for grinding. Examples: (*a*) *odd-toed:* horse, rhinoceros, tapir; (*b*) *even-toed:* ox, pig, sheep, deer.

ORDER VI. *Insectiv′ora.* Small, insect-eating, furry or spiny covered; long snout. Examples: mole, shrew, hedgehog.

ORDER VII. *Carniv′ora.* Long canine teeth, sharp and long claws. Examples : dog, cat, bear, seal, and sea lion.

ORDER VIII. *Chiroptera* (kī-rŏp′te-ra). Fore limbs adapted to flight, teeth pointed. Example: bat.

ORDER IX. *Primates* (prī-mā′tēz). Erect or nearly so, fore appendage provided with hand. Examples: monkey, ape, man.

**Summary.** — The mammals are vertebrates with hair, warm blood, four-chambered heart, and mammary glands. Economically they are of much importance as they furnish us with food, beasts of burden, clothing, etc. Some are of distinct harm, the rat being perhaps the greatest offender.

**Problem Questions.** — 1. Why are mammals considered the highest animals?

2. How would you distinguish a rodent? A carnivorous mammal? An ungulate?

3. Name the local mammals found in your community that are of value; of harm.

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## XXIII. MAN, A MAMMAL

***Problem.*** *To compare man as a vertebrate with the frog as to —*

(*a*) *Body covering.*

(*b*) *Muscles.*

(*c*) *Adaptations in the skeleton.*

(*d*) *Nervous system.*

(*Laboratory Manual, Prob. XLI; Laboratory Problems, Probs. 163 to 169.*)

**Man's Place in Nature.** — Although we know that man is separated mentally by a wide gap from all other animals, in our study of physiology we must ask where we are to place him structurally. If we attempt to classify man, we see at once he must be placed with the vertebrate animals because of his possession of a vertebral column. Evidently, too, he is a mammal, because the young are nourished by milk secreted by the mother and because his body has at least a partial covering of hair. Among the different orders of mammals man most closely resembles anatomically the one to which the monkeys and apes belong, called *primates*.

Although anatomically there is a greater difference between the lowest type of monkey and the highest type of ape than there is between the highest type of ape and the lowest savage, yet there is an immense mental gap between the ape and man.

**Evolution of Man.** — Undoubtedly there once lived upon the earth races of men who were much lower in their mental organization than the present inhabitants. If we follow the early history of man upon the earth, we find that at first he must have been little better than one of the lower animals. He was a nomad, wandering from place to place, living upon whatever animals he could kill with his hands and whatever edible plants he found. Gradually he learned to use weapons, with which to kill his prey, first using rough stone implements for this purpose.

As man became more civilized, implements of bronze and of iron were used. About this time the subjugation and domestication of animals began to take place. Man then began to cultivate the fields, and to have a fixed place of abode other than a cave. The beginnings of civilization were long ago, but even to-day the earth is not entirely civilized.

**The Races of Man.** — At the present time there exist upon the earth five races or varieties of man, each very different from the others in instincts, social customs, and, to an extent, in structure. These are the Ethiopian or negro type, originating in Africa; the Malay or brown race, from the islands of the Pacific; the American Indian; the Mongolian or yellow race, including the natives of China and Japan, and the Eskimos; and, finally, the Caucasians, represented by the civilized white inhabitants of Europe and America.

**The Human Body a Machine.** — In all animals, and the human animal is no exception, the body has been likened to a machine in that it turns over the *latent* or potential energy stored up in food into *kinetic* energy (mechanical work and heat), which is manifested when work is performed. One great difference exists between an engine and the human body. The engine uses fuel unlike the substance out of which it is made. The human body, on the other hand, uses for fuel the same substances as those out of which it is formed; it may, indeed, use part of its own substance for food. The human organism must do more than purely mechanical work; it must be so delicately adjusted to its surroundings that it will react in a ready manner to stimuli from without; it must be able to utilize its fuel (food) in the most economical manner; it must be fitted with machinery for transforming the energy received from food into various kinds of work; it must properly provide the machine with oxygen so that the fuel will be oxidized, and it must carry away the products of oxidation, as well as other waste materials which might harm the effectiveness of the machine. Most important of all, the human machine must be able to repair itself.

In order to understand better this complicated machine, the human body, let us examine the structure of its parts and thus

get a better idea of the interrelation of these parts and of their functions.

**Structure of the Skin.** — In man, the outer covering, or skin, is composed of two layers: the *epidermis* and the *dermis*. The outer part of the epidermis is made largely of flattened dead cells. It is this layer that peels off after sunburn, or that separates from the inner part of the epidermis when a water blister is formed. The inner cells of the epidermis are provided with more or less pigment or coloring matter. It is to the varying

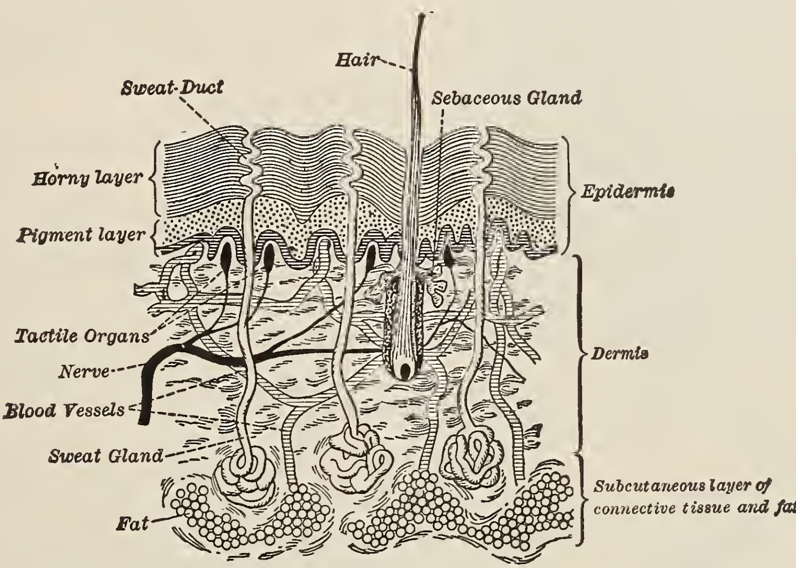



Diagram of a section of the skin. (Highly magnified.)

quantity of this pigment that the light or dark complexion is due. The inmost part of the epidermis is made up of small cells which are constantly dividing to form new cells to take the place of those in the outer layer which are lost.

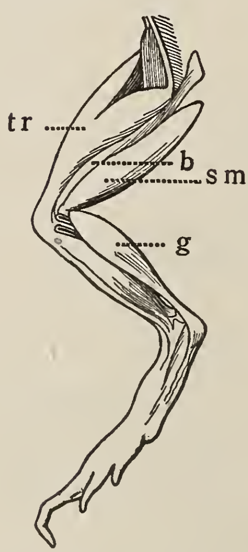
The *dermis*, or inner layer of the skin, is largely composed of connective tissue filled with a network of blood vessels and nerves. This layer contains the *sweat glands*, some of the most important glands in the body, and the *tactile cor′puscles*, which are connected with the nervous system, and cause this part of the skin to be sensitive to touch.

**Nails and Hair.** — Nails are a development from the horny layer of the epidermis. A hair is also an outgrowth of the horny

layer, although it is formed in a deep pit or depression in the dermis; this pit is called the *hair follicle.*

**The Glands of the Skin.** — Scattered through the dermis, and usually connected with the hair follicles, are tiny oil-secreting glands, the *sebaceous* (sē-bā′shus) *glands,* which keep the hair and surface of the skin soft. The other glands in the dermis, known as *sweat glands,* are to be found in profusion, over 2,500,000 being present in the skin of a normal man. These glands excrete certain wastes from the blood in the water they pass off. Thus the skin not only protects the body, but also serves as an excretory organ. Its most important function, however, is the regulation of the heat of the body. How it does this, we shall learn later. (See Chapter XXVII.)

**Connective Tissue.** — The layer immediately beneath the dermis is known as the *subcuta′neous* layer. It is an important storage place for fat. Underneath this layer we find a mass of flesh or *muscle.* Intermixed with this is a considerable amount of fat. The fat, muscle, — in fact, all the tissues in the body, — are held together by fibrous threads called *connective tissue.*

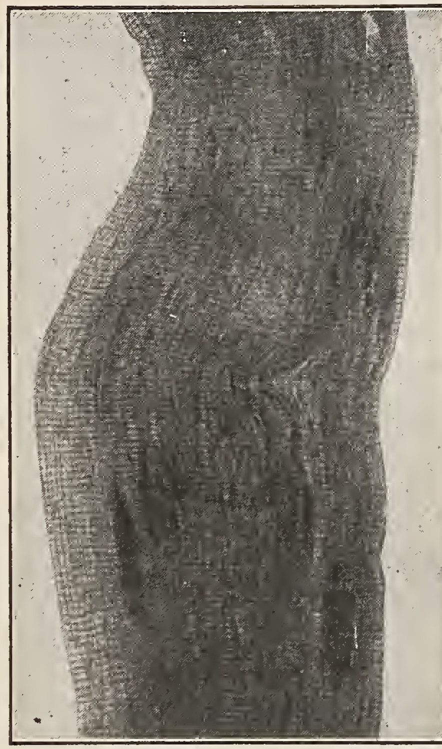


Frog's hind leg: *tr,* triceps, an extensor muscle; *sm,* a flexor muscle.

**Muscles and Movement.** — We are all aware that motion in any of the higher animals is caused by the action of the muscles, which contract to cause movement. In man and the other vertebrate animals, the muscles are almost always fastened to bones, which, acting as levers, give wide range of motion.

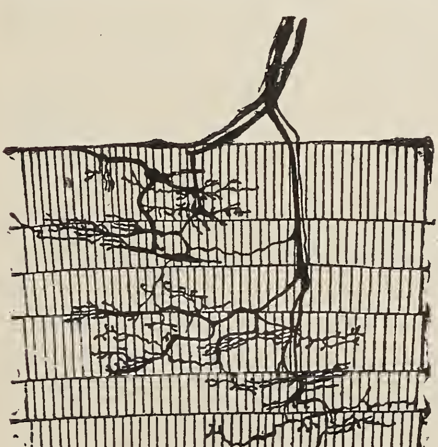
**Arrangement of Voluntary Muscles in the Human Body.** — Muscles are usually placed in pairs; one, called the *extensor,* serves to straighten the joint; the other, the *flexor,* bends the joint. Locate, by feeling the muscles when expanded and when contracted, the extensors and flexors in your own arm. This paired arrangement of muscles is of obvious importance, a flexor muscle balancing the action of an extensor on the other side of the

joint. The end of the muscle that has the wider movement in a contraction is called the *insertion;* the part that moves least is the *origin.*



A bit of voluntary muscle fiber, showing the cross striations as seen under the microscope. (Highly magnified.)

**Microscopic Structure of Voluntary Muscle.** — With a sharp pair of scissors cut through a muscle at right angles to the long axis; examination will show that it is composed of a number of bundles of fibers. These fibers are held together by a sheath of connective tissue. Each of these bundles may be separated into smaller ones. If we continue this so as to separate the smallest possible bits that can be seen with the naked eye, and then examine such a tiny portion under the compound microscope, it will present somewhat the appearance shown in the Figure. The muscle is seen to be made up of a number of tiny threads which lie side by side, held together by the sheath. Muscles, then, are bundles of long fibers. In man, muscles which are under the control of the will have a striated appearance, while those which are involuntary are unstriated. Both kinds are supplied with nerves, which control them (see Figures).



The delicate endings of nerves in voluntary muscle. (Highly magnified.)

**Muscle Tissue and its Uses.** — Muscles form a large part of the body, in man nearly half of his entire weight. Nearly every muscle in the human body is attached to a bone either at one or at both ends. Movement is performed by means of the muscles, leverage being obtained by their attachment to the bones. In the human body there are over five hundred muscles, varying from one smaller

than a pinhead to a band almost two feet in length. Every movement of the body, be it merely a change of expression or change in the pitch of the voice; directly results from contraction of a muscle. Muscles also give form to the body, and are useful in protecting the delicate organs and large blood vessels within them.

**Muscles and the Skeleton.** — Muscles would be of little use to animals if they were not attached to hard parts of the body which serve as levers. In many invertebrate animals (for example, crustaceans, insects, and mollusks), the muscles are attached to the exoskeleton. In man they are attached to the endoskeleton.

In the hind leg of a frog, if we cut through the muscles of the thigh to the bone, we may make out exactly how and where the muscles of the thigh are attached to the bone. Moving the leg in as many different directions as possible, we notice that it may be flexed or bent; that it may be extended to its original position; that it may be moved to and from the midline of the body; that, with the knee held stiff, the whole limb may be made to describe the arc of a circle.[1]

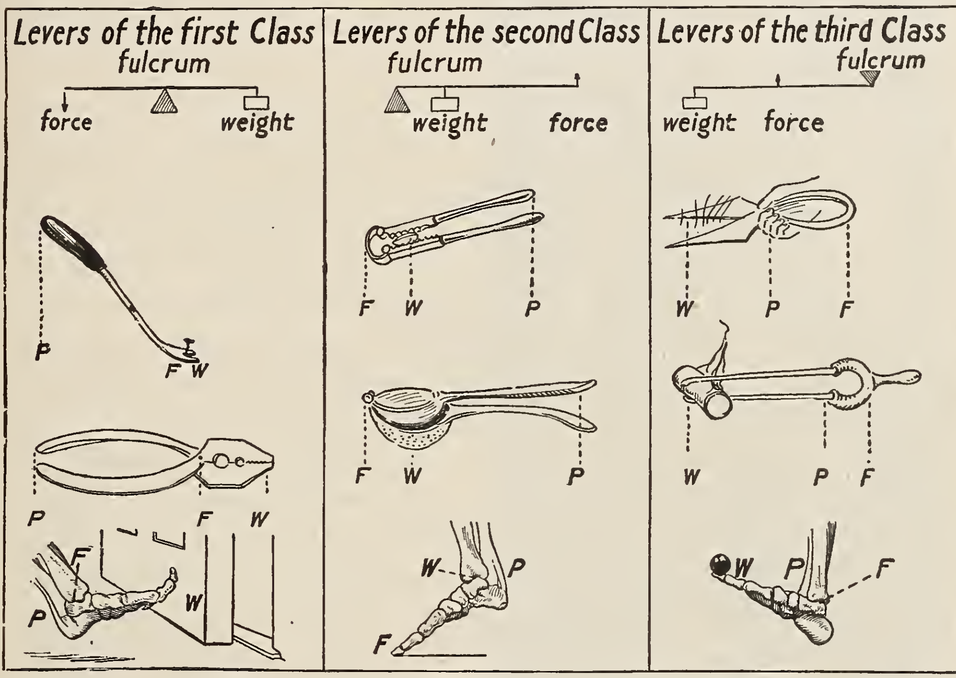
The same movements are possible in the leg of a man. This movement between bones is obtained by means of joints. If, in the frog, we carefully separate the muscles of the thigh to the bone, we find that they are attached to the bone by white, glistening *tendons*. Careful examination shows that the bones themselves are held together by very tough white bands or cords; these are the *ligaments*. We find, too, that one end of the large thigh bone fits into a socket in the hip bone or pelvic arch. It is thus easy to see how such free movement is obtained in the leg.

Hinge joint, showing muscle (*a*) and its tendon (*b*).

**Levers in the Body.** — It is evident that movement of a joint is caused by muscles which act in coöperation with the bones to which they are attached; the latter thus form true levers. A lever is a structure by which either *greater work power* or *greater range of motion* is obtained. In this apparatus, the lever works against a fixed point, the fulcrum, in order to raise a certain weight. A seesaw is a lever; here the fulcrum is in the middle, the weight is at one end, and the power to lift the weight is applied at the other end. There are three classes of levers, named according to the position of the fulcrum.

[1] At this point, if possible, demonstration with a human skeleton should be made.

In the first class, the fulcrum lies between the weight and the force or power; the seesaw is an example of this. The best example in the human body of a lever of the first class is seen when the head is raised. Here the fulcrum is the vertebra known as the *atlas;* the power is the muscles of the neck attached to the back of the skull and to the spine; the weight is




Three classes of levers: the first case shows pushing with the toe; the second, rising on the toe; the third, lifting with the toe.

the front part of the head. When one keeps the head erect, this lever is used; the nodding head when one is napping shows its action.

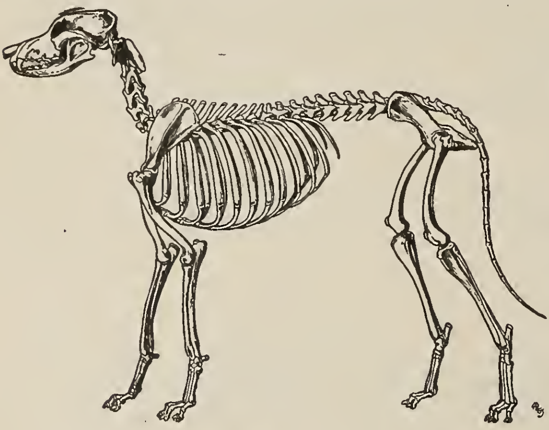
A lever of the second class has the fulcrum at one end, and the weight between it and the power; when we rise on our toes, we use this kind of lever.

In a lever of the third class, the fulcrum is at one end, with the power between it and the weight. This is the kind of lever seen most frequently in the human body. The flexing (drawing up) of the lower leg or the forearm is an example of the use of this kind of lever. In such a lever, a wide range of movement is obtained.

**General Structure and Uses of the Skeleton.** — Evidently bones form a framework to which muscles are attached; thus they are used as levers for purposes of movement. Second, they give protection to delicate organs; they form a case around

the brain and spinal cord; as ribs they protect the organs in the body cavity. Third, they give rigidity and form to the body.

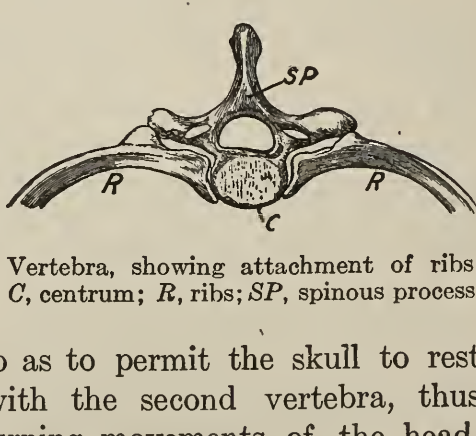
The skeleton of vertebrate animals consists of two distinct regions: a *ver'tebral column* or backbone which, with the skull, forms the *axial* skeleton; and the parts attached to this main axis, the *appen-dic'ular* skeleton (the appendages). All skeletons of vertebrates have the same general regions, the size and shape of the bones in these regions differing somewhat in each kind of animal.



Skeleton of a dog, a typical mammal.

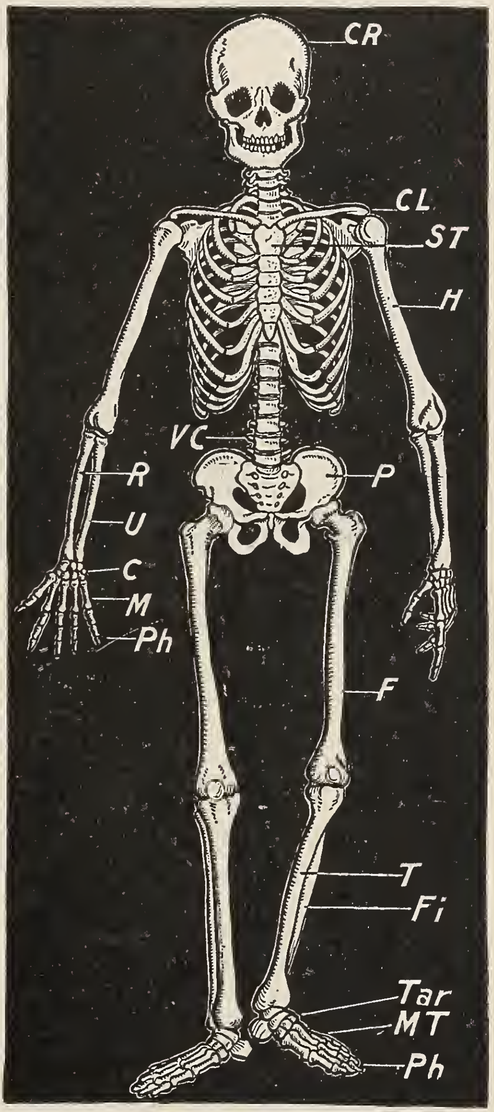
In the axial skeleton the vertebral column is made up of a number of bones of irregular shape, which fit more or less closely into each other. This can be seen easily in the frog. These bones are called *vertebræ.* They possess long processes to some of which the muscles of the back are attached. Certain of the vertebræ bear *ribs* (arched, flat bones), the special function of which is to protect the organs of the upper body cavity.

**Adaptations in the Vertebral Column.** — The vertebral column in a child is made of thirty-three separate pieces of bone; several of them grow together in the region of the pelvis and there are twenty-six in the adult. Each vertebra presents the general form of a body or *centrum* of bone and a bony arch with seven projections; in this arch runs the *spinal cord.* The vertebra directly beneath the head is modified so as to permit the skull to rest in it; this articulates freely with the second vertebra, thus permitting the nodding and turning movements of the head.




Vertebra, showing attachment of ribs: *C*, centrum; *R*, ribs; *SP*, spinous process.

Besides these individual adaptations, the vertebral column, as a whole, is peculiarly adapted to protect the brain from jar; this is seen in the double bend of the vertebral column and the pads of cartilage between the individual vertebræ. The whole column of vertebræ joined one above another supports the weight of the body. The largest vertebræ at the base of the column are joined to the huge pelvic bones to support the body above. That part of the vertebral column of man which bears the ribs is known as the *thoracic* (thŏ-răs′ĭk) *region.* The ribs, twelve pairs in number, are long, curved bones which combine lightness with strength; joined by elastic cartilage to the *sternum* in front and to the vertebræ behind, they form a wonderful protection to the organs in the thoracic cavity, and yet allow free movement in breathing.

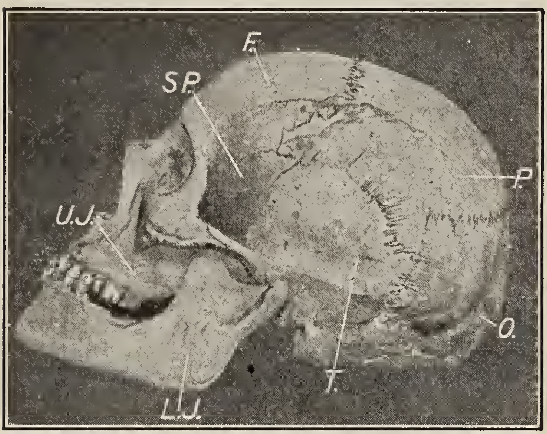



Skeleton of man: *CR*, cranium; *CL*, clavicle; *ST*, sternum; *H*, humerus; *VC*, vertebral column; *P*, pelvic girdle; *R*, radius; *U*, ulna; *C*, carpals; *M*, metacarpals; *Ph*, phalanges; *F*, femur; *T*, tibia; *Fi*, fibula; *Tar*, tarsals; *MT*, metatarsals.

**The Appendages.** — The parts of the skeleton to which the bones of the anterior and posterior appendages are attached are respectively known as the *pectoral girdle* (from which hangs the arm) and the *pelvic girdle* (which joins the leg bones to the axial skeleton).

The bones of the appendages attached to the pelvic girdle

are adapted peculiarly to locomotion and support; for this purpose the bones are long and strong, hinged by very flexible joints. In the hand the joints are especially free to allow for grasping. In the leg, where weight must be supported as well as carried, the bones are bound more firmly to the axial skeleton. The bones of the foot are so arranged that a springy arch is formed which aids greatly in locomotion.



The skull: *F.*, frontal bone; *P.*, parietal bone; *T.*, temporal bone; *SP.*, sphenoid bone; *O.*, occipital bone; *U.J.*, superior maxillary (upper jaw) bone; *L.J.*, inferior maxillary (lower jaw) bone.

**The Human Skull.** — The skull shows wonderful adaptations for protection; it is compactly built, and its arched roof gives strength. The eye and inner ear are protected in sockets of bone. The lower jaw works upon a hinge, and furnishes attachment for strong muscles which move the jaw.

**Other Organs.** — We have seen that a body cavity has developed in all animals which are more complex than the baglike hydra, and that a food tube has come to lie within this space. In all such animals the structures which have to do with digestion and absorption of food, most of those which have to do with the circulation of food and of the blood, and organs which give oxygen to the blood, as well as the organs of excretion and of reproduction, lie within the body cavity. These organs we shall discuss in detail later.

**Nerves.** — Nerves are found in practically all parts of the body, ending in the skin, in muscle, in the heart, lungs, and other organs, where they receive stimuli and control movements. The most important part of the nervous system in vertebrate animals lies within the cavity formed by bones making up the skull and the vertebral column. This central nervous system, consisting of the *spinal column* and the *brain*, is a characteristic of the vertebrates.

**General Functions of the Nervous System.** — We have seen that, in the simplest animals, one cell performs the functions necessary to its existence. In the more complex animals, where groups of cells form tissues, each having a different function, a nervous system is developed. *The functions of the human nervous system are:* (1) *to provide man with sensation, by means of which he becomes acquainted with the world about him;* (2) *to connect organs in different parts of the body so that they act as a united and harmonious whole;* (3) *to provide for the acts which we call voluntary.* Coöperation in word and deed is the end attained. We are all familiar with examples of the coöperation of organs. You see food; the thought comes that it is good to eat; you reach out, take it, raise it to your mouth; the jaws move in response to your will; the food is chewed and swallowed; while digestion and absorption of the food are taking place, the nervous system is still in control. The nervous system regulates the pumping of blood to all parts of the body, respiration, secretion of glands, and, indeed, every bodily function. Man is the highest of all animals because of the extreme development of the nervous system. Man is the thinking animal, and as such is master of the earth.

**Summary.** — Man is a mammal. He is also anatomically a complicated machine. This chapter has pointed out numerous adaptations in the skeleton and muscles of the body. It has also pointed out that coördination is brought about by means of the nervous system.

**Problem Questions.** — 1. Why is man a mammal?

2. Mention ten adaptations in the human skeleton.

3. How is movement brought about in the body?

4. What are the functions of the different parts of the nervous system of man?

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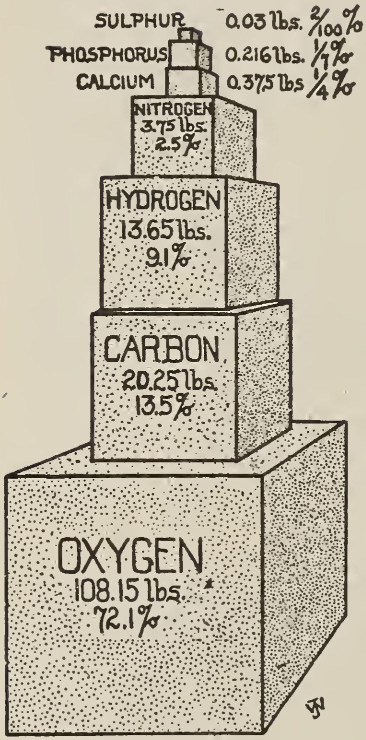
# XXIV. FOODS AND DIETARIES

***Problem.*** *A study of food values and diets to determine —*




The chief chemical elements of which the human body is composed, with percentage of each. The weight also is given, for a body weighing 150 pounds.

(*a*) *Food values and cost.*

(*b*) *Nutritive values as compared with cost.*

(*c*) *The family dietary.*

(*d*) *Food values.*

(*Laboratory Manual, Prob. XLII; Laboratory Problems, Probs. 170 to 178.*)

**Why we need Food.** — *We have already defined food as anything that forms material for the growth or repair of the body of a plant or animal, or that furnishes energy for it.* The millions of cells of which the body is composed must be given material which will form more living matter or material which can be oxidized to release energy when muscle cells move, or gland cells secrete, or brain cells think. Food, then, not only furnishes our body with material to grow, but also gives us the energy we expend in the acts of walking, running, breathing, and even in thinking.

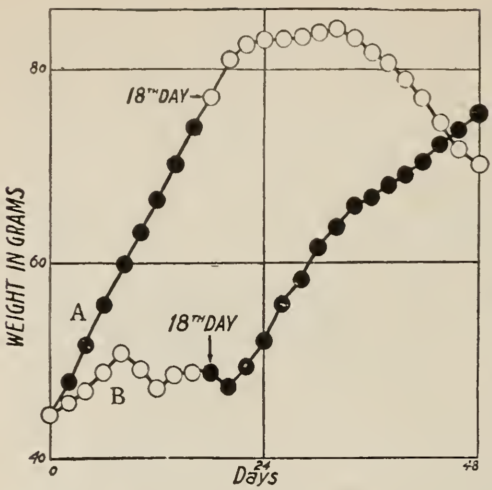
**Nutrients.** — Certain nutrient materials form the basis of food for both plants and animals. The organic nutrients have been found to be *proteins* (such as lean meat, eggs, the gluten of bread), *carbohydrates* (starches, sugars, gums, etc.), *fats* and *oils* (both animal and vegetable), and *vitamins*. The inorganic nutrients are *mineral matter* and *water*. The parts of the human body, be they muscle, blood, nerve, bone, or gristle, are built up from the nutrients in our food.

**Proteins.** — Proteins, in some manner unknown to us, are manufactured in the bodies of green plants. They contain the element nitrogen, and hence are called nitrogenous foods. Nitrogen, necessary for the growth of the body, can be used only when combined with other elements in the form of a compound. Man forms the protoplasm of his body (that is, the muscles, tendons, nervous system, blood corpuscles, the living parts of the bone and the skin, etc.) from nitrogenous food. Different proteins contain different amounts of available building material, hence some are more useful to the body than others. Proteins may also be used as fuel in the body. Some nitrogenous food man obtains by eating the flesh of animals, and some he obtains directly from plants (for example, peas and beans).

**Fats and Oils.** — Fats and oils, both animal and vegetable, are the materials from which the body derives part of its energy. The chemical formula of a fat shows that while it has considerable carbon and hydrogen in its molecule, there is very little oxygen present; hence the great capacity of this substance for uniting with oxygen. A pound of butter releases over twice as much energy to the body as does a pound of sugar or a pound of steak. Human fatty tissue is formed in part from fat in the food eaten, but carbohydrate or even protein food may be changed into fat and may be stored in the body as a reserve supply of fuel.

**Carbohydrates.** — The carbohydrates, like the fats, contain carbon, hydrogen, and oxygen. Here, however, the oxygen and hydrogen are united in the molecule in the same proportion as are hydrogen and oxygen in water. *Carbohydrates are essentially energy-producing foods.*

**Vitamins.** — Vitamins are not very well known but they have been proved to be necessary for life. They may be destroyed easily by heat in some foods, as milk, and endure a great deal of heat in others, as potatoes and tomatoes. Four or more vitamins have been identified: *A*, found in milk, butter, eggs, and some vegetables, as spinach, carrots, and sweet potatoes; *B*, found in the outer layers of cereals, in most vegetables and fruits, yeast, and milk; *C*, found in some fruits and vegetables; and *D*, found in milk and certain green vegetables. The action of the




The importance of vitamins. Two groups of rats were fed ample rations of protein, carbohydrate, fat, and mineral salts, similar to those in milk. In addition a minute quantity of milk, containing the vitamin missing from the regular rations, was given to group A only for the first seventeen days, and to group B only thereafter. What was the effect upon growth, as shown by the average weight?

third vitamin, *C*, is partly destroyed by heat, so preserving and canning foods render such foods less valuable as givers of vitamins.

Just what service the vitamins do is unknown, but we do know that if our diet does not contain all of them, growth will not take place and illness or even death may follow. Scurvy, beriberi, and probably rickets are due to the absence of certain vitamins.

**Inorganic Foods.** — Water forms a large part of almost every food substance. The human body, by weight, is about 65 per cent water. Water forms a large part of the blood and the digestive fluids, and a sufficient quantity is essential to health.


Foods rich in vitamins: "A" is contained in milk, butter, and eggs; "B," in vegetables, oranges, whole-wheat bread, and milk; "C," in oranges and fresh vegetables; and "D," in milk and green vegetables.

When we drink water, we take with it some of the inorganic salts used by the body in making bone and in the formation

| | "A" | "B" | "C" | "D" |
|---|---|---|---|---|
| BREAD, (WATER) | − | + | − | − |
| " , (MILK) | + | + | − | + |
| " , WHOLE WHEAT (WATER) | + | ++ | − | − |
| " , " " (MILK) | ++ | ++ | ? | + |
| BARLEY (WHOLE) | + | ++ | − | |
| CORN, YELLOW | + | ++ | − | |
| OATS | + | ++ | − | − |
| RYE, CRACKED | + | ++ | ? | |
| WHEAT, KERNEL | ++ | +++ | − | + |
| " , BRAN | + | +++ | − | |
| LIVER | ++ | ++ | ? | + |
| KIDNEY | ++ | ++ | + | + |
| BRAINS | + | ++ | ? | + |
| HEART | + | + | + | + |
| FISH, FAT | + | + | ? | − |
| " , ROE | + | ++ | ? | + |
| MILK, FRESH, (UNPASTEURIZED) | +++ | ++ | ++V | ++ |
| " , CONDENSED | +++ | ++ | +V | + |
| " , EVAPORATED | +++ | ++ | ? | |
| " , DRIED, (WHOLE) | +++ | ++ | +V | |
| " , SKIMMED | + | + | +V | |
| BUTTERMILK | + | ++ | +V | |
| CREAM | +++ | ++ | +V | |
| BUTTER | +++ | − | − | + |
| CHEESE | ++ | ++ | − | |
| EGGS | +++ | + | − | + |
| ALMONDS | + | ++? | * | |
| COCONUT | + | ++ | − | + |
| HICKORY NUTS | * | ++ | * | |
| PEANUTS | + | ++ | * | |
| WALNUTS | * | ++ | * | |

| | "A" | "B" | "C" | "D" |
|---|---|---|---|---|
| TOMATO (RAW OR CANNED) | ++ | +++ | +++ | |
| BEANS, KIDNEY | + | +++ | * | |
| " , NAVY | + | +++ | * | |
| " , STRING | ++ | ++ | + | |
| BEETS | − | + | + | |
| CABBAGE, RAW | ++ | +++ | +++ | |
| " , CANNED | * | * | ++ | |
| " , COOKED BRIEFLY | ++ | ++ | + | |
| CARROT, RAW | ++ | + | + | |
| " , COOKED | ++ | + | +V | |
| CAULIFLOWER | + | ++ | ? | |
| DANDELION GREENS | ++ | ++ | + | + |
| LETTUCE (GARDEN) | ++ | ++ | +++ | + |
| ONIONS | ? | ++ | ++ | |
| PARSNIP | − | ++ | ? | |
| PEAS, FRESH | ++ | ++ | +++ | + |
| POTATO (BOILED) | + | ++ | ++ | |
| SWEET POTATO | ++ | + | ? | |
| RUTABAGA | − | ++ | +++ | |
| SPINACH, FRESH | +++ | +++ | +++ | |
| " CANNED | +++ | + | +++ | |
| SQUASH | ++ | ? | ? | |
| TURNIPS | − | ++ | +++ | |
| APPLES | + | ++ | ++ | |
| BANANAS | ? | + | + | |
| GRAPE JUICE | ? | + | + | − |
| GRAPEFRUIT | ? | ++ | ++ | − |
| LEMON JUICE | − | ++ | +++ | |
| ORANGE JUICE | + | ++ | +++ | |
| PINEAPPLE (RAW OR CANNED) | ++ | ++ | +++ | |
| RASPBERRIES (RAW OR CANNED) | * | * | +++ | |
| PEACHES (RAW OR CANNED) | ++ | + | ++ | |

+ · · · contains the Vitamin
++ · · · good source of the Vitamin
+++ · · · excellent source of the Vitamin
− · · · no appreciable amount of the Vitamin
? · · · doubt as to presence or relative amount
* · · · evidence lacking or insufficient
V · · · variable

Vitamins in foods. From the American Medical Association.

of protoplasm. Sodium chloride (table salt), an important part of the blood, is taken as a flavoring upon our meats and vegetables. Phosphate of lime and potash are important factors in the formation of bone.

Phosphorus is a necessary element for making protoplasm. Milk, eggs, meat, whole wheat, and dried peas and beans contain small amounts of it. Iron also is an extremely important mineral, as it is used in the building of red blood cells. Meats, eggs, peas, beans, spinach, and prunes are foods containing some iron.

Some salts, compounds of calcium, magnesium, potassium, and phosphorus, have been recently found to aid the body in many of its most important functions. The beating of the heart, the contraction of muscles, and action of the nerves appear to be due to the presence of minute quantities of these salts in the body.

**Uses of Nutrients.** — The following table sums up the uses of nutrients to man:

| | | |
|---|---|---|
| Protein . . . . . . . . . . . . White (albumen) of eggs, curd (casein) of milk, lean meat, gluten of wheat, etc. | Forms tissue (muscles, tendon, and probably fat). | All serve as *fuel* and yield *energy* in form of heat and muscular strength. |
| Fats . . . . . . . . . . . . . . Fat of meat, butter, olive oil, oils of corn and wheat, etc. | Form fatty tissue. | |
| Carbohydrates . . . . . . . . Sugar, starch, etc. | Transformed into fat. | |
| Vitamins . . . . . . . . . . . | Accessory substances of unknown composition that seem to be regulating and growth promoting. They are essential to life. | |
| Mineral matters (ash) . . . . Phosphates of lime, potash, soda, etc. | Aid in forming bone, assist in digestion, etc. | |

**Fuel Values of Nutrients.** — In planning for the diet best fitted for our daily requirements the food used for energy in the body is stated in heat units called *cal'ories*. *A calorie (large calorie) is the amount of heat required to raise the temperature of one kilogram of water one degree Centigrade.* This is about equivalent to raising one pound of water four degrees Fahrenheit. The fuel value of different foods may be computed accurately by burning a given portion (say one pound) in the apparatus known as a *calorim'eter*.

**The Best Diet.** — Inasmuch as all living substance contains nitrogen, it is evident that protein food must form a part of the dietary; but protein alone will not support life. If more protein is eaten than the body requires, immediately the liver and kidneys have to work overtime to get rid of the excess of protein which forms poisonous wastes.

It has been found that a man who does muscular work requires a little less than one quarter of a pound of protein, the same amount of fat, and about one pound of carbohydrate to provide for the growth, waste, and repair of the body and the energy used up in one day. Put in another way, Atwater's standard for a man at light exercise is food enough to yield 2816 calories; of these, 410 calories are from protein, 930 calories from fat, and 1476 calories from carbohydrate. That is, for every 100 calories furnished by the food, 14 are from protein, 32 from fat, and 54 from carbohydrate. In actual amount, the day's ration as advocated by Atwater would contain about 100 grams or 3.7 ounces protein, 100 grams or 3.7 ounces fat, and 360 grams or 13 ounces carbohydrate. Professor Chittenden of Yale University, another food expert, thinks we need proteins, fats, and carbohydrates in about the proportion of 1 to 3 to 6, thus differing from Atwater in giving less protein in proportion. Chittenden's standard for the same man is food to yield a total of 2360 calories, of which protein furnishes 236 calories, fat 708 calories, and carbohydrates 1416 calories. For every 100 calories furnished by the food, 10 are from protein, 30 from fat, 60 from carbohydrate. In actual amount the Chittenden diet would contain 2.16 ounces protein, 2.83 ounces fat, and 13 ounces carbohydrate.[1] A German named Voit gives as ideal 25 proteins, 20 fat, 55 carbohydrate, out of every 100 calories; this is nearer our actual daily ration. In addition, an ounce of salt and nearly one hundred ounces of water containing the necessary mineral salts, are used in a day.

In addition to this the diet must include foods containing vitamins. By means of the table on the following page (from Atwater [2]), which shows the composition of some food materials, the nutritive and fuel value of the foods may be seen at a glance. The amount of *refuse* contained in foods (such as the bones of meat or fish, the exoskeleton of crustaceans and mollusks, the woody coverings of plant cells) is also shown in this table.

[1] Page 18, Bul. 6, Cornell Reading Course.

[2] W. O. Atwater, *Principles of Nutrition and Nutritive Value of Food*, U.S. Department of Agriculture.

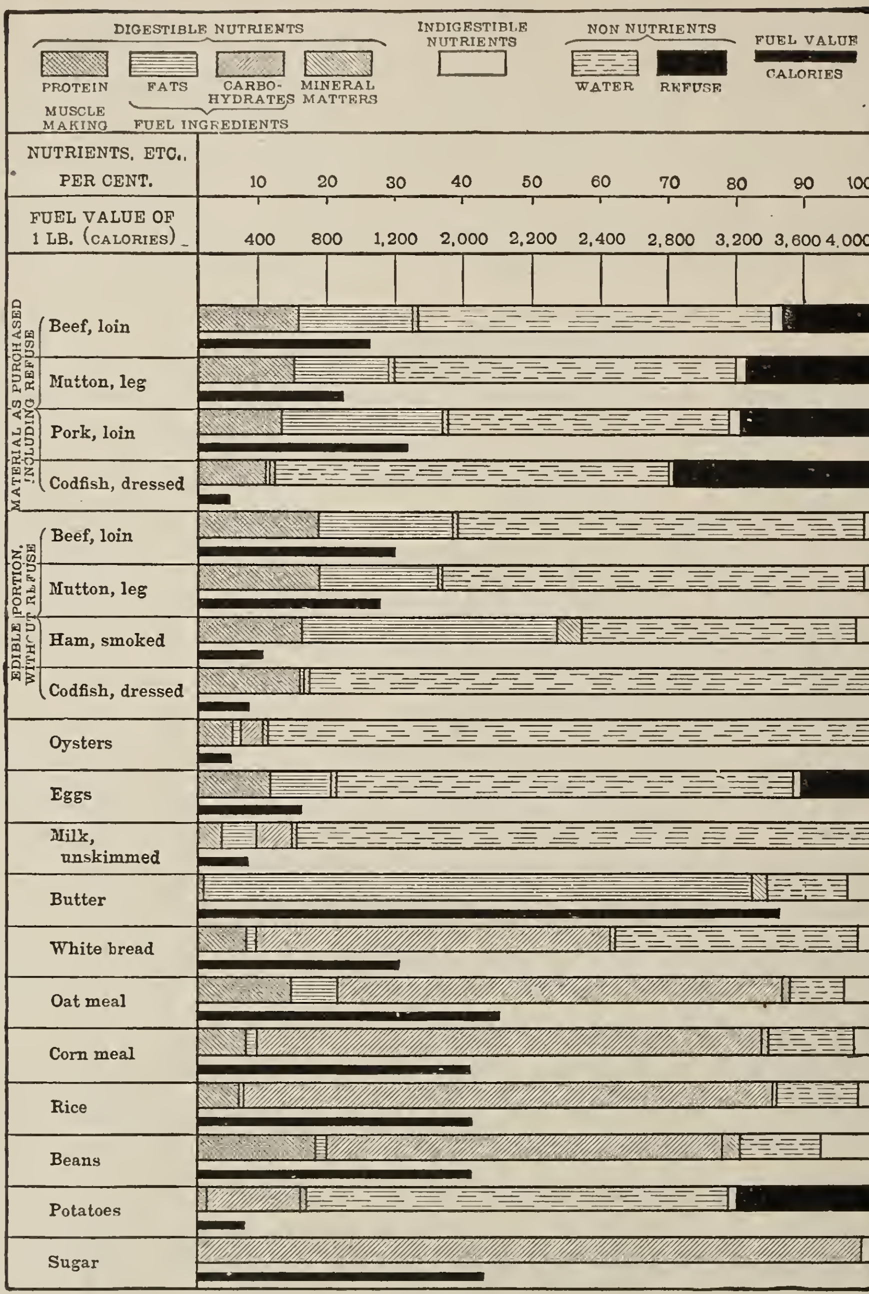
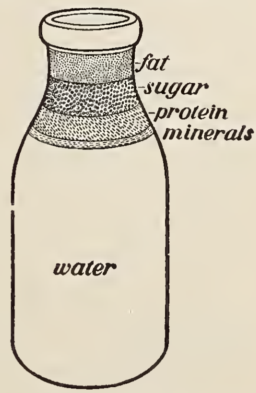



Table of food values. Determine the percentage of water in codfish, loin of beef, milk, potatoes. Percentage of refuse in leg of mutton, codfish, eggs, and potatoes. What is the refuse in each case? Find three foods containing a high percentage of protein; of fat; of carbohydrate. Find some food in which the proportions of protein, fat, and carbohydrate are combined in the right proportions.

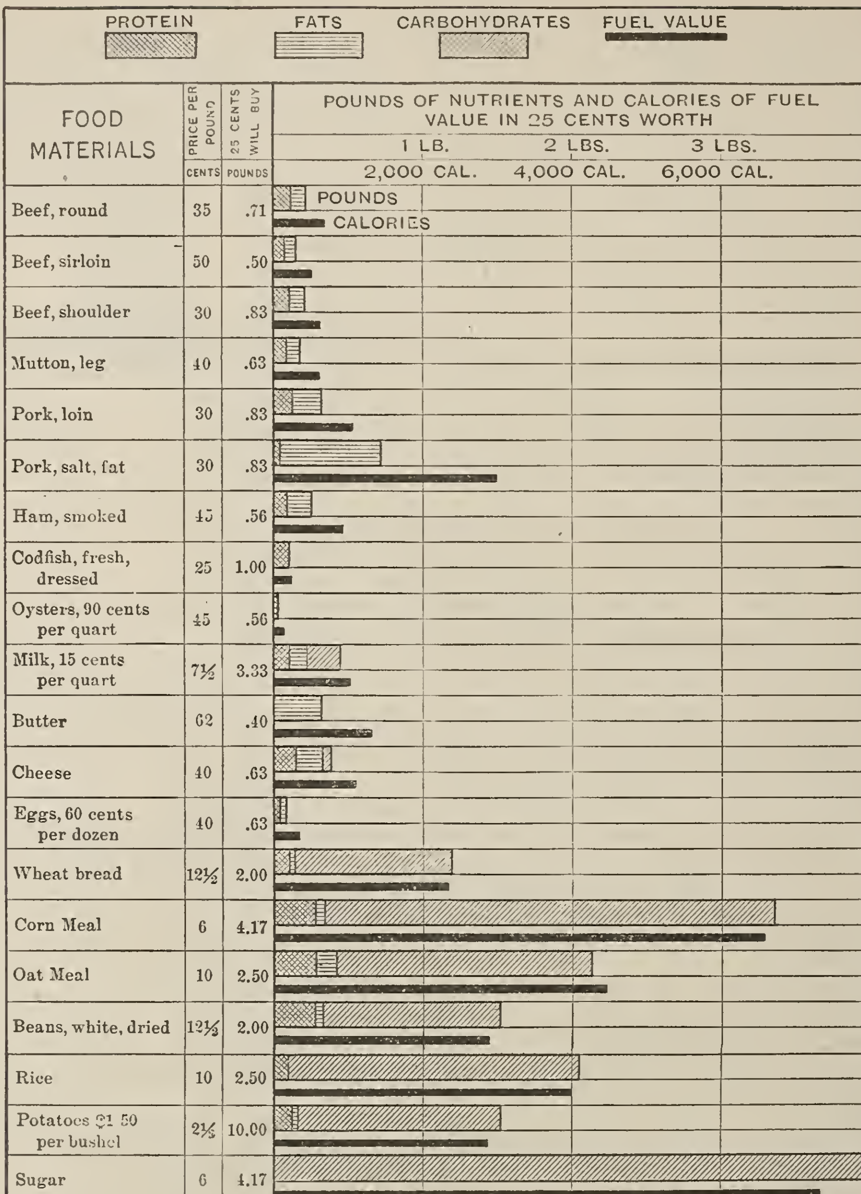
**A Mixed Diet Best.** — Knowing the proportion of the different food substances required by a man and the ones containing the vitamins, it will be an easy matter to determine from this table the best foods for use in a mixed diet. Meats contain so much nitrogen that they should be eaten with other foods. In milk, the proportion of proteins, carbohydrates, and fats is nearly right to make protoplasm; a considerable amount of mineral matter and at least two of the vitamins being also present. For these reasons, milk is extensively used as a food for children. Why? Some vegetables (for example, peas and beans) contain the nitrogenous material needed for protoplasm formation in considerable proportions, but in a less digestible form than is found in some other foods. A purely vegetable diet contains much waste material, such as the cellulose forming the walls of the plant cells, which is indigestible. The Japanese army ration used to consist almost entirely of rice. A recent report by their surgeon-general intimates that the diminutive stature of the Japanese may, in some part at least, have been due to this diet. A mixed diet should contain all the nutrients in a digestible form and not too much hard indigestible material.




The composition of a bottle of milk. Why is milk considered a good food?

**The Relation of Work to Diet.** — It has been shown experimentally that a man doing hard muscular work needs more food than one doing light work. The mere exercise gives the individual a hearty appetite; he eats more because he needs more of all kinds of food than if he were doing light work. Especially is it true that the person of sedentary habits who gets little exercise should be careful not to overeat and to eat food that will digest easily. Protein food should also be reduced. Rich and hearty foods may be left for the man who is doing hard manual labor out of doors, who has a good digestion doubtless, and needs the energy for extra work

**The Relation of Environment to Diet.** — We are all aware of the fact that the body seems to crave heartier food in winter

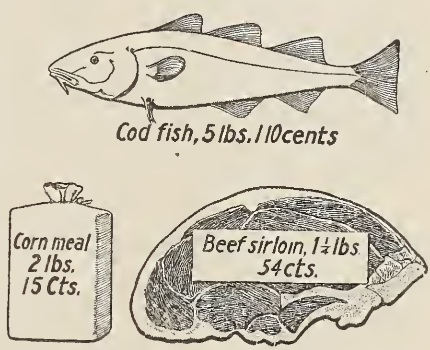



| FOOD MATERIALS | PRICE PER POUND (CENTS) | 25 CENTS WILL BUY (POUNDS) |
|---|---|---|
| Beef, round | 35 | .71 |
| Beef, sirloin | 50 | .50 |
| Beef, shoulder | 30 | .83 |
| Mutton, leg | 40 | .63 |
| Pork, loin | 30 | .83 |
| Pork, salt, fat | 30 | .83 |
| Ham, smoked | 45 | .56 |
| Codfish, fresh, dressed | 25 | 1.00 |
| Oysters, 90 cents per quart | 45 | .56 |
| Milk, 15 cents per quart | 7½ | 3.33 |
| Butter | 62 | .40 |
| Cheese | 40 | .63 |
| Eggs, 60 cents per dozen | 40 | .63 |
| Wheat bread | 12½ | 2.00 |
| Corn Meal | 6 | 4.17 |
| Oat Meal | 10 | 2.50 |
| Beans, white, dried | 12½ | 2.00 |
| Rice | 10 | 2.50 |
| Potatoes $1.50 per bushel | 2½ | 10.00 |
| Sugar | 6 | 4.17 |

Table showing the cost of various foods. Using this table, make up an economical dietary for one day, three meals, for a man doing moderate work. Give reasons for the amount of food used and for your choice of foods. Make up another dietary in the same manner, using expensive foods. What is the difference in your bill for the day?

than in summer. The temperature of the body is maintained at $98\frac{1}{2}°$ in winter as in summer, although much more heat is lost from the body in the cold weather. Hence in winter the heat-producing foods should be increased to provide for a greater supply of fuel and of energy because we exercise more in cold weather. We may use carbohydrates for this purpose, as they are economical and are digested more easily than fats. The inhabitants of cold countries get their heat-releasing foods largely from fats, because less plant food is produced there. In tropical countries and in hot weather little protein should be eaten and a considerable amount of fresh fruit should be used.

**Food Economy.** — The American people are far less economical in their purchase of food than most other nations. Nearly one half of the total income of the average workingman is spent on food. He spends a large amount on food, partly because he wastes money in purchasing expensive and unnecessary foods. A comparison of the daily diets of persons in various occupations in this and other countries shows that as a rule we eat more than is required to supply the necessary amount for fuel and on repair, and that our workingmen eat more than those of other countries. Another waste of money by the American is in the false notion that a large proportion of the daily dietary should be meat. Many people think that the most expensive cuts of meat are the most nutritious. The falsity of this idea may be seen by a careful study of the table on page 330, compiled by Atwater, which shows the relative amount of various foods purchasable for 25 cents.



Three portions of food, each containing the same amount of nourishment.

**Daily Fuel Needs of the Body.** — It has been pointed out that the daily diet should differ widely according to age, occupation, time of year, etc. A boy requires slightly more than a girl. The following table shows the daily fuel needs for several ages and occupations: —

Daily Calorie Needs (Approximately)

| Obs. | | |
|---|---|---|
| 1. | For child under 2 years | 900 Calories |
| 2. | For child 2–5 years | 1200 Calories |
| 3. | For child 6–9 years | 1500 Calories |
| 4. | For child 10–12 years | 1800 Calories |
| 5. | For child 12–14 (woman, light work also) | 2100 Calories |
| 6. | For boy (12–14), girl (15–16), man sedentary | 2400 Calories |
| 7. | For boy (15–16) (man, light muscular work) | 2700 Calories |
| 8. | For man, moderately active muscular work | 3000 Calories |
| 9. | For farmer (busy season) | 3200 to 4000 Calories |
| 10. | For ditchers, excavators, etc. | 4000 to 5000 Calories |
| 11. | For lumbermen, etc. | 5000 and more Calories |

**Normal Heat Output.** — We know that different amounts of energy are released by the body at different times and under different conditions. The following table gives the result of some experiments made to determine the hourly and daily expenditure of energy of the average normal grown person when asleep and awake, at work or at rest.

Average Normal Output of Heat from the Body

| Conditions of Muscular Activity | Average Calories per Hour |
|---|---|
| Man at rest, sleeping | 65 Calories |
| Man at rest, awake, sitting up | 100 Calories |
| Man at light muscular exercise | 170 Calories |
| Man at moderately active muscular exercise | 290 Calories |
| Man at severe muscular exercise | 450 Calories |
| Man at very severe muscular exercise | 600 Calories |

It is very simple to use such a table in calculating the number of calories which are spent in twenty-four hours under different bodily conditions. For example, suppose the case of a clerk or school-teacher leading a relatively inactive life, who

| | | |
|---|---|---|
| sleeps for 9 hours | × 65 Calories = | 585 |
| works at desk 9 hours | × 100 Calories = | 900 |
| reads, writes, or studies 4 hours | × 100 Calories = | 400 |
| walks or does light exercise 2 hours | × 170 Calories = | 340 |
| | | 2225 |

This comes out, as we see, very close to example 6 of the table [1] on page 332.

**How we may find whether we are eating a Properly Balanced Diet.** — We already know approximately our daily calorie needs and about the proportion of protein, fat, and carbohydrate required. Dr. Irving Fisher of Yale University has worked out a very easy method of determining whether one is living on a proper diet or not. He has made up a number of tables, parts of which are shown on page 334,[1] in which he has designated portions of food, each portion furnishing 100 calories of energy. The tables show the proportion of protein, fat, and carbohydrate in each food, so that it is a simple matter by using such tables to estimate the proportions of the various nutrients in our dietary. We may rely with safety upon a diet based upon either Atwater's, Chittenden's, or Voit's standard. From the tables on page 334 make out a simple dietary for yourself, first estimating your own needs in calories and then picking out 100 calorie portions of food which will give you the proper proportions of protein, fat, and carbohydrate.

**Food Waste in the Kitchen.** — Much loss occurs in the improper cooking of foods. Meats especially, when overdone, lose much of their flavor and are far less easily digested than when they are cooked properly. The chief reasons for cooking meats are that the muscle fibers may be loosened and softened, in which condition they are digested more easily, and that the bacteria and other parasites in the meat may be killed by the heat. The common method of frying makes foods difficult to digest. A good way to prepare meat, either for stew or soup, is to place the meat, cut in small pieces, in cold water, and allow it to simmer for several hours. Rapid boiling toughens the muscle fibers just as the white of egg becomes solid when heated. Boiling and roasting are excellent methods of cooking meat. In order to prevent the loss of the nutrients in roasting, it is well to baste the meat frequently; thus a crust is formed on the outer surface of the meat, which prevents the escape of the juices from the inside.

[1] The above tables and those which follow have been taken from the excellent pamphlet of the Cornell Reading Course, No. 6, *Human Nutrition*.

TABLES OF FOOD VALUES, UNITS AND WEIGHTS

| NAME OF FOOD | PORTION CONTAINING 100 CALORIES | WEIGHT OF 100 CALORIES | CALORIES FURNISHED BY | | |
| --- | --- | --- | --- | --- | --- |
| | | | Prot. | Fat | Carbo. |
| 1. *Vegetable* | | *Ounces* | | | |
| Crackers | 2 crackers | .9 | 10 | 20 | 70 |
| Wheat bread | Thick slice | 1.3 | 9 | 7 | 84 |
| Corn meal | Cereal dish | .96 | 10 | 5 | 85 |
| Oatmeal | 1½ servings | 5.6 | 18 | 7 | 75 |
| Beans (baked) | Side dish | 2.66 | 21 | 18 | 61 |
| Rice | Cereal dish | 3.1 | 10 | 1 | 89 |
| Sugar | 3 teaspoonfuls | .86 | — | — | 100 |
| Potatoes (boiled) | 1 large size | 3.62 | 11 | 1 | 88 |
| Cabbage | 4 servings | 11 | 20 | 8 | 72 |
| Tomatoes | 4 average servings | 15.2 | 21 | 7 | 72 |
| Lettuce | 5 average servings | 18 | 25 | 14 | 61 |
| 2. *Animal* | | | | | |
| Beef (sirloin) | Small steak | 1 4 | 31 | 69 | — |
| Brisket | Ordinary serving | 1.30 | 42 | 58 | — |
| Mutton (leg) | Large serving | 1.2 | 35 | 65 | — |
| Pork (loin) | Small serving | .97 | 18 | 82 | — |
| Ham | Ordinary serving | 1.1 | 28 | 72 | — |
| Veal (leg) | Large serving | 2.4 | 73 | 27 | — |
| Chicken | Large serving | 3.2 | 79 | 21 | — |
| Codfish | 2 servings | 4.9 | 95 | 5 | — |
| Oysters | 1 dozen | 6.8 | 49 | 22 | 29 |
| Lobster | 2 servings | 4.1 | 78 | 20 | 2 |
| Eggs | 1 large egg | 2.1 | 32 | 68 | — |
| 3. *Dairy products* | | | | | |
| Whole milk | Small glass | 4.9 | 19 | 52 | 29 |
| Buttermilk | 1½ glasses | 9.7 | 34 | 12 | 54 |
| Butter | Small pat | 0.44 | 0.5 | 99.5 | — |
| Cheese (Amer.) | 1½ cubic inches | .77 | 25 | 73 | 2 |
| 4. *Fruits, nuts, etc.* | | | | | |
| Bananas | 1 large | 3.5 | 5 | 5 | 90 |
| Oranges | 1 large | 9.4 | 6 | 3 | 91 |
| Watermelon | 1 whole | 27.0 | 6 | 6 | 88 |
| Apples | 2 | 7.3 | 3 | 7 | 90 |
| Peanuts | 13 | .62 | 20 | 63 | 17 |
| Chocolate | ⅓ square | .56 | 8 | 72 | 20 |

Vegetables are cooked in order that the cells containing starch grains may be burst open. This allows the starch to be more easily reached by the digestive fluids. Inasmuch as water may dissolve out nutrients from vegetable tissues, it is best to boil them rapidly in a small amount of water. This gives less time for the solvent action to take place. Vegetables should be cooked with the outer skin left on when it is possible.

**Problem.** *To determine some forms of food adulterations.* (*Laboratory Manual, Prob. XLIII; Laboratory Problems, Prob. 179.*)

**Adulterations in Foods.** — The addition of some cheaper or non-nutritious substance to a food, with the view to cheating the purchaser, or the replacing of some of the nutritive substances with something less nutritious, is known as *adulteration.* One of the commonest adulterations is the substitution of grape sugar (glucose) for cane sugar. Most cheap candy is adulterated thus. Flour and other cereal foods are sometimes adulterated with some cheap substitutes, as bran or sawdust. Coffee, cocoa, and spices have been in the past subject to great adulteration; cottonseed oil is often substituted for olive oil; oleomargarine has been too frequently sold for butter; while honey, sirups of various kinds, cider and vinegar, have all been found to be either artificially made from cheaper substitutes or to contain such substitutes. Sausage may have a cheap cereal substituted for meat in it.

Probably the food which suffers most from adulteration is milk, as water can be added without the average person being the wiser. By means of an inexpensive instrument known as a *lactom'eter*, this cheat may easily be detected. In most cities, the milk supply is carefully safeguarded, because of the danger of spreading typhoid fever from impure milk. Milk was formerly often treated with preservatives which kill the bacteria in it and prevent the milk from souring rapidly. Such preservatives, as formaldehyde, are harmful to health.

**Pure Food Law.** — Thanks to the National Pure Food Law passed by Congress in 1906, and to the activity of various city and state boards of health, the opportunity to pass adulterated

foods on the public is now greatly lessened. This law, which does not work so well in the case of drugs and patent medicines, has prevented adulteration of many articles by setting up standards of purity for food products and by requiring proper labels on all goods put up in packages, such as canned goods, jams, jellies, etc. Thus we may at least know when we buy adulterated or artificially colored foods. The law also requires the inspection of all animal products shipped from one state to another.

**Impure Water.** — Great danger comes from drinking impure water. This subject has already been discussed under Bacteria, where it was seen that the spread of typhoid fever in particular is due to a contaminated water supply. As citizens we must aid all legislation that will safeguard the water used by our towns and cities. Boiling water for ten minutes or longer will render it safe from all germs.

**Stimulants.** — We have learned that food is anything that supplies building material or releases energy in the body; but some materials used by man, presumably as food, do not come under this head. Such are tea and coffee. When taken in moderate quantities, *they produce a temporary increase in the vital activities* of the person taking them, *but they neither build tissue nor release energy and hence are stimulants,* not foods. Tea and coffee when used in moderation often appear to be harmless to adults, but they are sometimes stimulating and a few people cannot use either without ill effects, even in small quantity. It is the *habit* formed by relying upon the stimulation given by tea or coffee that makes them a danger to man. In large amounts, they are undoubtedly injurious because of a stimulant called *caffeine* (kăf′ē-ĭn) in coffee and *the′ine* in tea. Cocoa and chocolate, although both contain a stimulant like caffeine, are in addition good foods, having from 12 per cent to 21 per cent of protein, from 29 per cent to 48 per cent fat, and over 30 per cent carbohydrate in their composition.

**Is Alcohol a Food?** — The question of the use of alcohol has been of late years a matter of absorbing interest and importance among physiologists. A few years ago Dr. Atwater performed a series of very careful experiments by means of the respiration

calorimeter, to ascertain whether alcohol is of use to the body as food or not.[1] In these experiments the subjects were given, instead of their daily allotment of carbohydrates and fats, enough alcohol to supply the same amount of energy that these foods would have given. The amount was calculated to be about two and one half ounces per day, about as much as would be contained in a bottle of light wine.[2] This alcohol was administered in small doses six times during the day. Professor Atwater's results may be summed up briefly as follows: —

1. The alcohol administered was almost all oxidized in the body.
2. The potential energy in the alcohol was transformed into heat or muscular work.
3. The body did about as well with the rations including alcohol as it did without it.

The committee of fifty eminent men appointed to report on the physiological aspects of the drink problem reported that a large number of scientific men stated that they were in the habit of taking alcoholic liquor in small quantities, and many reported that they did not feel harm thereby. A number of scientists seem to agree that when taken in small quantities alcohol may be a kind of food, although a very *poor* kind.

On the other hand, we know that although alcohol may technically be considered as a food, it is very unsatisfactory and, as the following statements show, it has a harmful effect on the nervous system which foods do not have.

**Alcohol a Poison.** — A commonly accepted definition of *a poison* is that it *is any substance which, when taken into the body, tends to cause the death or serious detriment to the health of the organism.* That alcohol may do this is well known by scientists. A study of the causes of death in the vital statistics of state or city shows a surprisingly large number of deaths from alcoholism,

[1] Alcohol is made up of carbon, oxygen, and hydrogen. It is very easily oxidized, but it cannot, as is shown by the chemical formula, be of use to the body in tissue building, because of its lack of nitrogen.

[2] Alcoholic beverages contain the following proportions of alcohol: beer, from 2 to 5 per cent; wine, from 8 to 20 per cent; liquors, from 30 to 70 per cent. Patent medicines frequently contain as high as 45 per cent alcohol. (See page 340.)

in spite of the Eighteenth Amendment. And now that home-made substitutes for the more carefully manufactured alcoholic drinks are consumed by hundreds of thousands of lawbreakers, the chances of alcoholic poisoning are very great.

Taken in small quantities alcohol acts as a quick stimulant. In large quantities it is a narcotic and paralyzes the nervous system.

But a more serious charge against alcohol is that it acts as a habit-forming drug. People who "get the craving" unfortunately cannot break away easily from the overwhelming desire to drink. This habit results all too often in degradation and death.

Dr. Kellogg, of the Battle Creek Sanitarium, points out that strychnine, quinine, and many other drugs are oxidized in the body, but surely cannot be called foods. The following reasons for not considering alcohol a food are taken from his writings: —

"1. A habitual user of alcohol has an intense craving for his accustomed dram. Without it he is entirely unfitted for business. One never experiences such an insane craving for bread, potatoes, or any other particular article of food.

"2. By continuous use the body acquires a tolerance for alcohol. That is, the amount which may be imbibed and the amount required to produce the characteristic effects first experienced gradually increase until very great quantities are sometimes required to satisfy the craving which its habitual use often produces. This is never the case with true foods. . . . Alcohol behaves in this regard just as does opium or any other drug. It has no resemblance to a food.

"3. When alcohol is withdrawn from a person who has been accustomed to its daily use, most distressing effects are experienced. . . . Who ever saw a man's hand trembling or his nervous system unstrung because he could not get a potato or a piece of cornbread for breakfast? In this respect, also, alcohol behaves like opium, cocaine, or any other enslaving drug.

"4. Alcohol lessens the appreciation and the value of brain and nerve activity, while food reënforces nervous and mental energy.

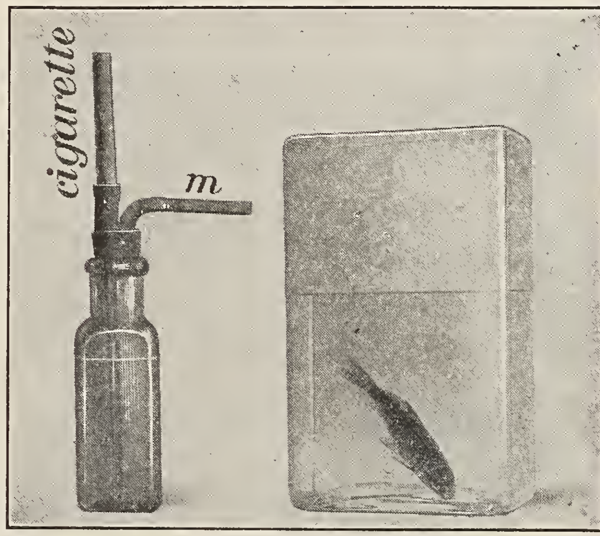
"5. Alcohol as a protoplasmic poison lessens muscular power, whereas food increases energy and endurance.

"6. Alcohol lessens the power to endure cold. This is true to such a marked degree that its use by persons accompanying Arctic expeditions is absolutely prohibited. Food, on the other hand, increases ability to endure cold. The temperature after taking food is raised. After taking alcohol, the temperature, as shown by the thermometer, is lowered.

"7. Alcohol cannot be stored in the body for future use, whereas all food substances can be so stored.

"8. Food burns slowly in the body, as it is required to satisfy the body's needs. Alcohol is readily oxidized and eliminated, the same as any other oxidizable drug."

**The Use of Tobacco.** — A well-known authority defines a narcotic as a substance "*which directly induces sleep, blunts the senses, and, in large amounts, produces complete insensibility.*" Tobacco, opium, chloral, and cocaine are examples of narcotics. Tobacco owes its narcotic influence to a strong poison known as nicotine, the use of which in killing insect parasites on plants is well known. In experiments with jellyfish and other lowly organized animals, the author has found as small a quantity as one part of nicotine to one hundred thousand parts of sea water to be sufficient to affect profoundly an animal placed within it. The illustration here given shows its effect upon a fish. Nicotine in a pure form is so powerful a poison that two or three drops would be sufficient to cause the death of a man by its action on the nervous system, especially the nerves controlling the beating of the heart.




Experiment (by Davison) to show how tobacco affects the nervous system. The nicotine caught in the water by passing through it the smoke from six cigarettes, was sufficient to kill the fish in the jar.

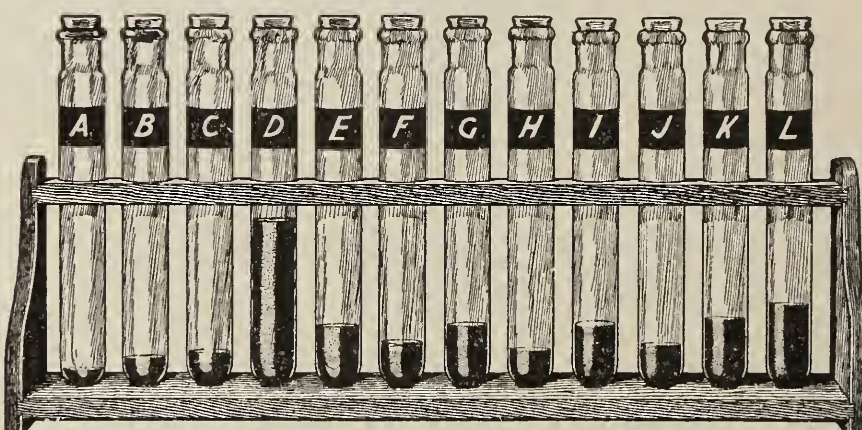
The action of tobacco is well known among boys training for athletic contests. The heart is affected and boys become "short-winded" as a result. The brain becomes stupefied and incapable of doing its best work. It has been demonstrated that tobacco has an important effect also on muscular development, as shown by the stunted appearance of the young smoker.

The West Point and Annapolis academies forbid the use of tobacco, and college coaches insist that men training for the teams shall not use it. Investigations made on college students show that groups of smokers matched against non-smokers were found to do poorer work in their studies, to graduate at a later date, and to grow more slowly. The use of tobacco is associated with lack of application and of ambition. The college cigarette fiend is usually the college loafer.

There is very complete agreement among teachers of boys below college age that the use of tobacco is very harmful and should at least be left alone until the boy is full grown.

**Problem.** — *A study of some medical frauds. (Laboratory Manual, Prob. XLIV; Laboratory Problems, Probs. 180–183.)*

**Use and Abuse of Drugs.** — The American people are addicted to the use of drugs and, especially, patent medicines. A




The amounts of alcohol in some liquors and in some patent medicines.

*A*, beer, 5%; *B*, claret, 8%; *C*, champagne, 9%; *D*, whiskey, 50%; *E*, well-known sarsaparilla, 18%; *F*, *G*, *H*, much-advertised nerve tonics, 14%, 18%, 12%; *I*, another much-advertised sarsaparilla, 18%; *J*, a well-known tonic, 14%; *K*, *L*, bitters, 20%, 25% alcohol.

glance at the street car advertisements shows this. Most of the medicines advertised contain alcohol in greater quantity than beer or wine, and many of them have opium, morphine, or cocaine in their composition. These drugs, in addition to being harmful, affect the person using them in such a manner that he soon feels the need for the drug. Thus the drug habit is formed, — a condition which has wrecked thousands of lives.

The American Medical Association, by means of its publications, is doing a great work in showing the public some of the frauds which are practiced by the patent medicine interests. It is shown, for example, that most cough medicines (or, as they used to be known, consumption cures) contain heroin or other habit-forming drugs, or else alcohol enough to act as a " bracer" and thus delude the poor victim into thinking he is better. A great number of the bitters or sarsaparillas contain enough alcohol to make them sought after in these days of prohibition. Some patent medicines, especially those with trade names, are simply fakes and the buyer pays $1.00 or more for materials that could be purchased in the drug store for a few cents.

A good rule to observe with reference to patent medicines is not to use any unless ordered to do so by a reliable physician. It is time that the thinking American public should wake to the fact that it is not only being cheated but also harmed physically by the patent medicines of which it is so fond.

**Summary.** — Certain nutrients, organic or inorganic, form the basis of all foods. The organic nutrients are carbohydrates, fats or oils, proteins, and vitamins. The first two groups contain the elements C, H, O — protein contains N also. Examples of proteins are meats and eggs; of carbohydrates, cereals and most vegetables; of fat, butter. There are also mineral salts and mysterious substances known as vitamins which make up an essential part of a dietary.

It has been determined that a mixed diet is necessary to support life; besides a proportion of the organic nutrients, it must contain inorganic salts as well.

**Problem Questions.** — 1. What is a food?

2. What is a calorie? How is it determined?

3. What is a balanced diet? Give examples.

4. Why are certain vegetables included in a balanced diet?

5. What are cheap foods? Expensive foods? Give examples.

6. What are the daily calorie needs and how are they determined?

7. Give some standards for a well-balanced diet.

8. What is a 100 calorie portion? Illustrate.

9. Describe the Pure Food Act of 1906.

10. What is an adulterant? Is adulterated food always harmful?

11. Is alcohol a food? Is it a poison?

12. Why are patent medicines harmful?

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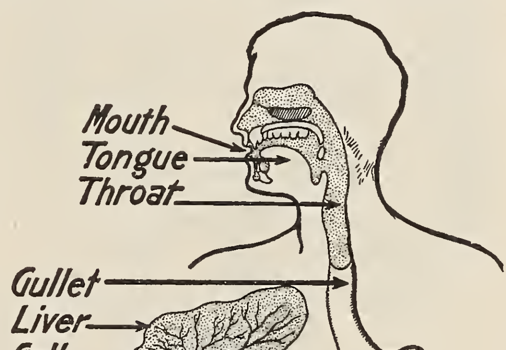
## XXV. DIGESTION AND ABSORPTION

**Purpose of Digestion.** — We have learned that the starch and protein food of plants is formed in the leaves. A plant, however, is unable to make use of the food in this condition. Before it can be transported from one part of the plant body to another, it is changed into a soluble form. Much the same condition exists in animals. In order that food may be of use to man, it must be changed into a soluble form that will allow its passage through the walls of the alimentary canal, or food tube. *Digestion consists in the changing of foods from an insoluble to a soluble form, so that they may pass through the walls of the alimentary canal and become part of the blood.*



Organs of Digestion.

**Problem.** — *Study of the digestive system of a frog in order better to understand that of man. (Laboratory Manual, Prob. XLV; Laboratory Problems, Probs. 184 to 186.)*

**Alimentary Canal.** — In all vertebrate animals, including man, food is normally taken in the mouth and passed through a food tube during the process of digestion. This tube is composed of different portions, named,

respectively, as we pass from the *mouth*, posteriorly, the *gullet*, *stomach*, and *small* and *large intestine.*

**Glands.** — In addition to the alimentary canal proper, we find a number of *digestive glands*, varying in size and position connected with the canal. As we have already learned, a *gland* is a collection of cells which takes up materials from the blood and pours them out as a secretion. They are like the nectar glands of a flower.

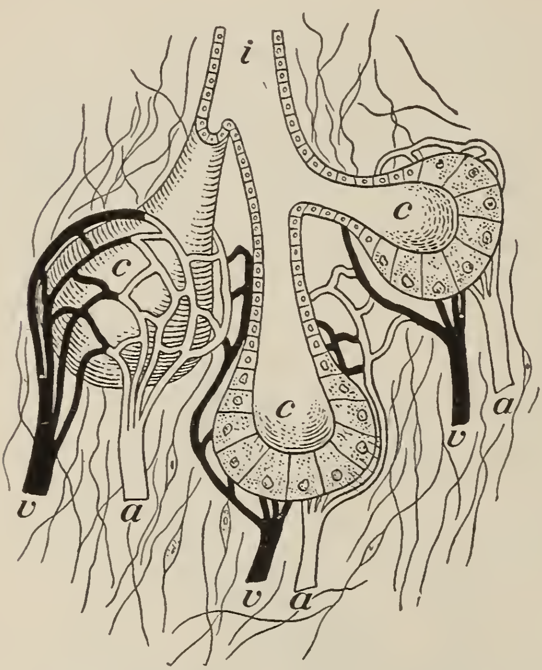



Diagram of a gland: *i*, the common tube which carries off the secretions formed in the cells lining the cavity *c*; *a*, arteries carrying blood to the cells; *v*, veins taking blood away from the cells.

Certain substances called *enzymes*, formed by glands, cause the digestion of food. The enzymes are made in the cells of the glands and poured out with the fluid secretion into the food tube, where they act upon insoluble foods and change them to a soluble form.

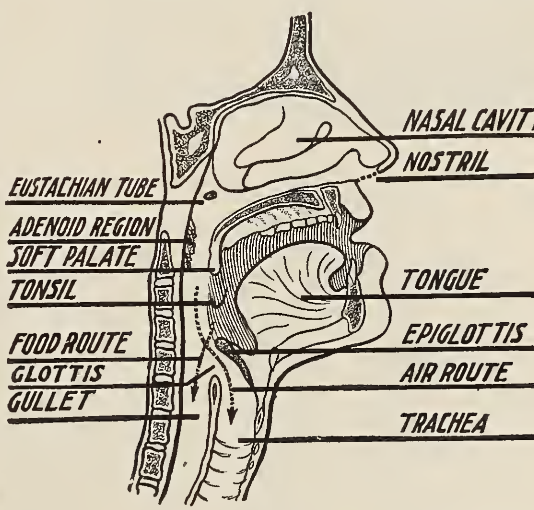
**Structure.** — The walls of the food tube are muscular and composed of long fibers which run lengthwise and small circular fibers passing like rings around the tube. The contraction of these muscles is very important in regulating the movement of the food. The entire inner surface of the food tube is covered with a soft lining of *mu'cous membrane.* This is always moist because certain cells, called *mucus cells,* empty their contents into the food tube, thus lubricating its inner surface. Where a large number of secreting cells are collected together, the surface of the food tube becomes indented to form a pitlike *gland.* Often such depressions are deep and branched, thus giving a greater secreting surface, as is seen in the Figure. The cells of the gland are always supplied with blood vessels and

nerves, for the secretions of the glands are under the control of the nervous system. Think of a sour pickle and note what happens.

Attached to the digestive tract of man are found the *salivary* glands in the walls of the mouth, *gastric* glands in the walls of the stomach, the *liver* and the *pan'creas,* two large glands which empty into the small intestine just below the stomach, and *intestinal glands* in the walls of the intestine.

It will be the purpose of this chapter to follow the various food substances as they pass through the food tube in order to find *how* and *where* the changes take place in the various nutrients which prepare them to become part of the blood.

**Mouth Cavity in Man.** — In our study of a frog we found that the mouth cavity has two unpaired tubes and four arranged in pairs leading from it. These are (*a*) the *gullet* or food tube, (*b*) the *windpipe* (in the frog opening through the *glottis*), (*c*) the paired nostril holes (*posterior na'res*), (*d*) the paired *Eustachian* (ū-stā'-kĭ-an) *tubes,* leading to the ear. All of these openings are found in man.

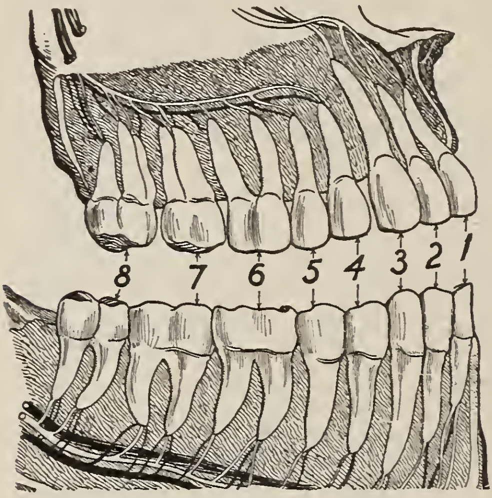


Mouth cavity of man.

The roof of the mouth is formed in front by a plate of bone called the *hard palate,* and in back by a softer continuation called the *soft palate,* which separate the nose cavity from that of the mouth. That part of the space back of the soft palate is called the *phar'ynx,* or throat cavity, from which pass out the *gullet* and the *windpipe.* The lower part of the mouth cavity is occupied by a muscular tongue. Examination of its surface with a looking-glass shows it to be almost covered in places by tiny projections called *papil'læ.* These papillæ contain organs known as *taste buds,* the sensory endings through which we determine the taste of sub-

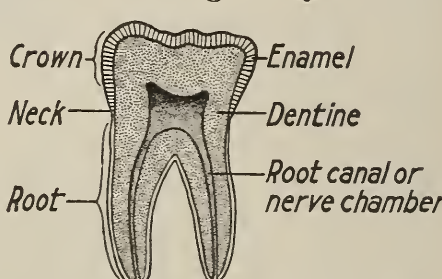
stances. The tongue is used in moving food about in the mouth, in starting it on its way to the gullet, and plays an important part, as we know, in speaking.

**The Teeth.** — The thirty-two teeth of man are divided, according to their functions, into four groups. In the center of each jaw in front are found four teeth with chisel-like edges; these are the *inci'sors,* or cutting teeth. On each end of these groups is found a single tooth, four in all, with rather sharp points; they are the *canines;* look for them in a cat or dog. Two teeth on each side, back of these, eight in all, are called *premolars.* Lastly, beyond the premolars are the *flat-top molars,* or grinding teeth, of which there are six in each jaw. Food is caught between irregular projections on the surface of the molars and crushed to a pulpy mass.



The teeth on the right side of both jaws: 1, 2, incisors; 3, canines; 4, 5, premolars; 6, 7, 8, flat-top molars.

**Care of the Teeth.** — Form the habit early in life of brushing the teeth upon getting up in the morning and just before going to bed at night. A vertical movement of the brush should be used between the teeth so as to dislodge bits of food caught there. The gums should be brushed as well so as to help the circulation of the blood there. A weak acid tooth wash, made of equal parts of vinegar and water, is helpful, as is a powder containing ground pumice. Can you see the use of each of these?



Longitudinal section of a tooth (a flat-top molar).

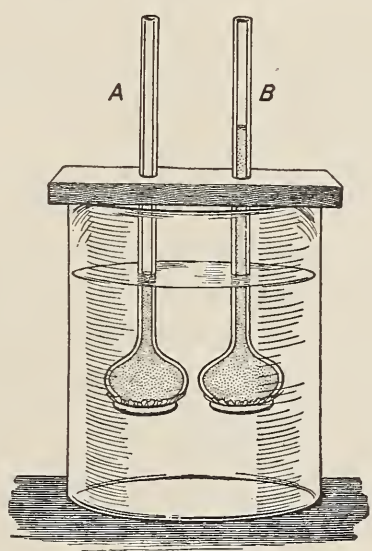
**Internal Structure of a Tooth.** — If a tooth is cut lengthwise, it is found to be hollow; this cavity, called the *pulp cavity,* corresponds to the cavity containing marrow in bones. In life it contains living material — the blood

vessels, nerves, and cells which build up the bony part of the tooth. The bulk of the hard part of the tooth consists of a limy material called *dentine* (dĕn′tĭn). Outside of this is a very hard substance called *enamel;* this substance, the hardest in all the body, is thickest on the exposed surface or crown of the tooth. Each tooth is held in its place in the jawbone by a thin layer of bony substance called *cement.*

**Problem.** — *How foods are chemically prepared for absorption into the blood. (Laboratory Manual, Prob. XLVI; Laboratory Problems, Probs. 187 to 193.)*

(*a*) *In the mouth.*
(*b*) *In the stomach.*
(*c*) *In the small intestine.*

**Salivary Glands.** — We are all familiar with the substance called *saliva* which acts as a lubricant in the mouth. Saliva is manufactured in the cells of three pairs of glands which empty into the mouth, and which are called, according to their position, the *parot′id* (under the ear), the *submax′illary* (under the jawbone), and the *sublin′gual* (under the tongue).



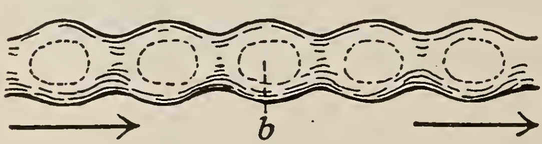
Experiment showing non-osmosis of starch and water in tube *A* and osmosis of sugar solution in tube *B*.

**Digestion of Starch.** — If we collect some saliva in a test tube, add to it a little starch paste, place the tube containing the mixture for twenty minutes in tepid water, and then test with Fehling's solution, we shall find grape sugar present. Careful tests of the starch paste and of the saliva made separately will usually show no grape sugar in either. If another test be made for grape sugar, after starch paste, saliva, and a few drops of any weak acid have been mixed for twenty minutes, the starch will be found not to have changed. The digestion of starch to grape sugar is caused by the presence in the saliva of an *enzyme*, or *digestive ferment*. You remember that starch in the growing corn grain was changed to grape

sugar by an enzyme called diastase. Here the same action is caused by an enzyme called *ptyalin* (tī'a-lĭn). This ferment, as we can prove, acts *only* in a slightly alkaline or neutral medium at about the temperature of the body.

**How Food is Swallowed.** — After food has been chewed and mixed with saliva, it is rolled into little balls and pushed by the tongue into such position that the muscles of the throat cavity may seize it and force it downward. Food, in order to reach the gullet from the mouth cavity, must pass over the *glottis,* the opening into the windpipe or *trachea.* When food is in the course of being swallowed, the upper part of this tube forms a trap-door, called the *epiglot'tis,* over the opening. When this trap-door is not closed, and food "goes down the wrong way," we choke, and the food is expelled by coughing.

**The Gullet, or Esophagus.** — In man this part of the food tube is much longer proportionately than in the frog. Like the rest of the food tube it is lined by soft and moist mucous membrane. The wall is made up of two sets of muscles, — the inside ones running around the tube; the outer band of muscle taking a longitudinal course. After food leaves the mouth cavity, it gets beyond our direct control, and the muscles of the gullet, stimulated to activity by the presence of food in the tube, push the food down to the stomach by a series of *peristal'tic* contractions. The gullet passes directly through a muscular partition, the *diaphragm* (dī'a-frăm), which is lacking in the frog. The diaphragm separates the heart and lungs from the other organs of the body cavity.

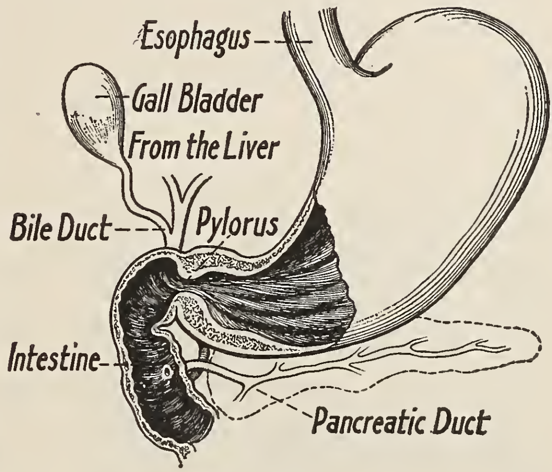



Peristaltic waves in the gullet of man: *b*, bolus or little ball of food.

**Stomach.** — The stomach is a pear-shaped organ capable of holding about three pints. The end opposite to the gullet, which empties into the small intestine, is provided with a ring of muscle forming a valve called the *pylo'rus.*

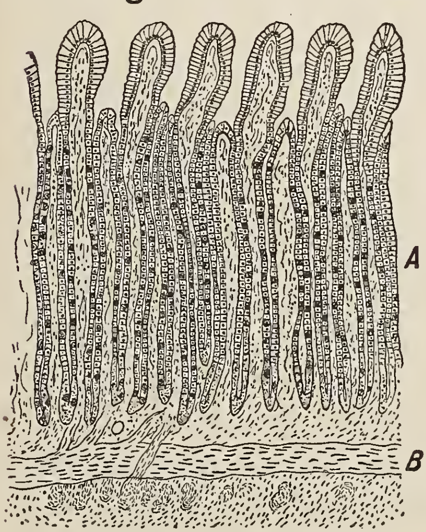
**Gastric Glands.** — The inner wall of the stomach has long folds which run lengthwise. Between the folds are tiny pits, or the openings of the *gastric glands* which lie imbedded in the wall of

the stomach. The gastric glands are little tubes, the lining of which secretes the *gastric juice*, a fluid which is poured into the stomach to assist in the digestion of food. This fluid is largely water. It is slightly acid in its chemical reaction, containing about 0.2 per cent *free hydrochloric acid.* It also contains a very important enzyme called *pepsin*, and another less important one called *rennin.*




Stomach and beginning of small intestine.

**Action of Gastric Juice.** — If protein is treated with artificial gastric juice at the temperature of the body, it will be found to become swollen and then gradually to change to a substance which is soluble in water. Most protein substances are insoluble and contain amino-acids which are separated by digestion. These amino-acids are used in building up the cells of the body and eventually become protoplasm.




Section through wall of the stomach, much magnified: *A*, gastric glands; *B*, muscular fibers.

One enzyme of gastric juice, called *rennin*, curdles or coagulates a protein found in milk; after the milk is curdled, the pepsin is able to act upon it. "Junket" tablets, which contain rennin, are used in the kitchen to cause this change.

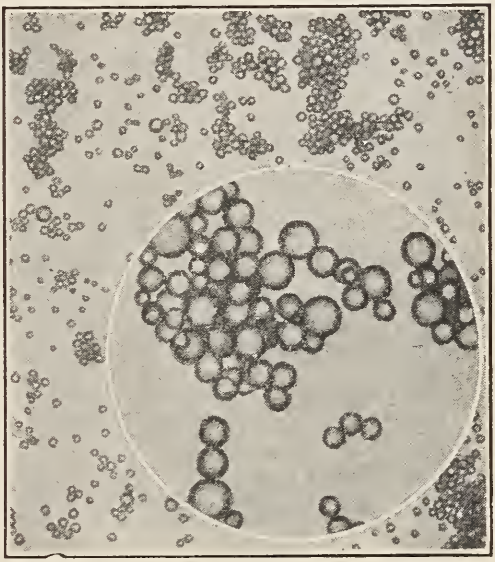
The hydrochloric acid found in the gastric juice acts upon lime and some other salts taken into the stomach with food, dissolving them so that they may pass into the blood and eventually form the mineral part of bone or of other tissue.

**Hormones and their Work.** — The modern study of physiology is fascinating because we are just beginning to find causes for some of the complicated actions that go on in the body. Many of the happenings, such as the secretion of gastric juice at a time when it will do the most good (when food is in the stomach), seems to be brought about by a substance formed in some of the cells lining the walls of the stomach. This substance is one of a group of mysterious regulative agents called *hormones* (hôr′mōnz). They are formed in groups of gland cells (the *ductless glands*) or in cells scattered throughout other organs, as in the walls of the stomach and intestine and in the pancreas and liver. The secretions, however, reach the blood stream and are carried to various parts of the body. The regulative action of different hormones is undoubtedly the factor which causes growth of various parts of the body and promotes the smooth running of a series of events which take place, for example, in digestion. Here one organ after another takes up the work of digesting its part of the meal, the initiative to do this work at the right moment being brought about by different hormones, which, at just the right moment, call the gland cells to do their work.

**Movements of the Stomach.** — The stomach walls are muscular and as soon as food reaches the stomach the action of these muscles begins and keeps the food in constant motion. Thus the food is gradually mixed with gastric juice and some digestion takes place. These movements are of much use in softening and breaking up the food and when it finally leaves the stomach it is in a semi-fluid condition with few large lumps of undigested matter. When food is thoroughly acidulated by means of the gastric hydrochloric acid, the ring of muscle around the pyloric end of the stomach relaxes and little gushes of food are allowed to pass into the small intestine. As soon as this acid substance strikes the walls of the small intestine a hormone made there is at once released into the blood, and the liver and the pancreas are made to pour out their digestive fluid.

**The Pancreas.** — The pancreas, a diffuse gland opening into the small intestine just below the pylorus, is one of the most important digestive glands of the body

Starch added to artificial pancreatic fluid and kept at blood heat is soon changed to sugar. Proteins, under the same conditions, are separated into amino-acids. Fats, which so far have been unchanged except to be melted by the heat of the body, are changed by the action of the pancreas into a form which can pass through the walls of the intestine. These changes are brought about by means of three enzymes: *amylop'sin,* which acts upon starches, *trypsin,* which acts upon proteins, and *lip'ase* or *steap'sin,* which acts upon fats. Pancreatic fluid also contains a milk-curdling enzyme. If we test pancreatic fluid we find it strongly *alkaline* in its reaction. If two test tubes, one containing olive oil and water, the other olive oil, water, and a weak solution of caustic soda, an *alkali,* be shaken violently and then allowed to stand, the oil and water will quickly separate, while the oil, caustic soda, and water will remain for some time in a milky *emulsion.* Pancreatic fluid similarly emulsifies fats and changes them into soft soaps and fatty acids in which form they may be absorbed.



Milk, a form of emulsion, as seen under the microscope. The fat globules appear in groups. In the circle one group is highly magnified.

**Liver.** — The liver is the largest gland in the body. It is of a deep red color. In man it hangs just below the diaphragm, a little to the right side of the body. It is divided into three lobes, between two of which is the *gall bladder,* a thin-walled sac which holds the *bile,* a secretion of the liver. Bile is a strongly alkaline fluid of golden brown color which becomes green on exposure to the air. It reaches the intestine through a common opening with the pancreatic fluid. Almost one quart of bile is passed daily into the intestine.

**Functions of Bile.** — The same hormone which causes

the secretion of pancreatic fluid also causes the flow of bile. The most important function of bile seems to be assisting the pancreatic juice to digest and absorb fats. If two funnels, each containing filter paper, one moistened with bile, and the other dry, be filled with oil, the oil will be found to pass through the moistened filter paper with much greater ease than through the dry one. Bile is slightly antiseptic and thus may help prevent fermentation within the intestine by keeping down the growth of bacteria.

**Formation of Glycogen.** — Perhaps the most important function of the liver is the formation of a material called *gly'cogen*, or animal starch. A large amount of blood received by the liver comes directly from the walls of the stomach and intestine, so that the liver normally contains about one fifth of all the blood in the body. This blood is very rich in food materials, and from it the cells of the liver take out materials necessary to form glycogen, which is then stored in the liver. When food which can be oxidized quickly is needed, the glycogen is changed to sugar and carried off by the blood to the tissues which require it, and there used for this purpose. Glycogen is also stored in the muscles, where it is oxidized to release energy when the muscles are exercised.

**Small Intestine.** — The process of digestion is carried on not only in the mouth and stomach, but also in the small intestine. This organ is described on the following page, in connection with absorption. In the walls of the small intestine are numerous small *intestinal glands* which pour their secretions into the tube and assist the pancreatic fluid in digesting starch, protein, and oils.

***Problem.*** — *A study to determine where and how digested foods pass into the blood.* (*Laboratory Manual, Prob. XLVII; Laboratory Problems, Probs. 194 to 197.*)

**The Absorption of Digested Food into the Blood.** — The object of digestion is to change foods from an insoluble to a soluble form. This has been seen in the study of the action of the various digestive fluids in the body, each of which aids in dissolving solid foods, and, in case of the bile, actually assist-

ing them to pass through the walls of the intestine. A small amount of digested food is absorbed by the blood in the walls of the stomach. Most of the absorption, however, takes place through the walls of the small intestine.

**Structure of the Small Intestine.** — The small intestine in man is a slender tube nearly twenty feet in length and about one inch in diameter. Its walls contain muscles which, by a series of slow waves of contraction, force the material within gradually toward the posterior end. The peristaltic movements of the muscles of the coats are of very great importance in the process of absorption, and these movements are caused to a great extent (as is the secretion of the various glands of the digestive system) by the mechanical stimulus of the food within the food tube. As one function of the small intestine is absorption, we must look for adaptations which increase the absorbing surface of the tube. This is gained in part by the inner surface of the tube being thrown into transverse folds which not only retard the rapidity with which food passes down the intestine, but also give more absorbing surface. But far more important for absorption are millions of little projections called *villi* (singular, *villus*), which cover the inner surface of the small intestine.

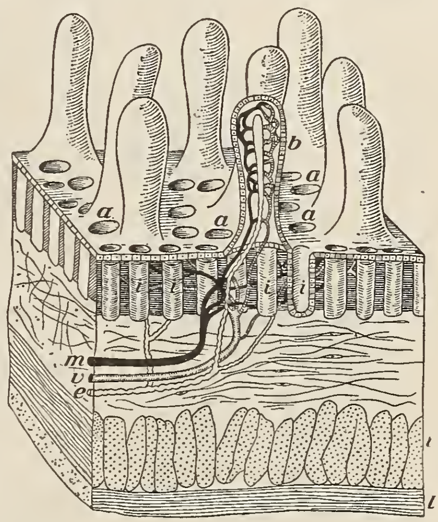



Diagram of a bit of the wall of the small intestine, greatly magnified. *a*, mouths of intestinal glands; *b*, villus cut lengthwise to show blood vessels and lacteal (in center); *e*, lacteal sending branches to other villi; *i*, intestinal glands; *m*, artery; *v*, vein; *l*, *t*, muscular coats of intestine wall.

**The Villi.** — So numerous are these projections that the whole surface presents a velvety appearance. The villi form the chief organs of absorption in the intestine, several thousand being distributed over every square inch of surface. By means of the folds and the villi the small intestine is estimated to have an absorbing surface equal to twice that of the surface of the

body. The internal structure of a villus is best seen in a longitudinal section. The outer wall is made up of a thin layer of cells which absorb the digested food from within the intestine. Underneath these cells lies a network of very tiny blood vessels, while inside of these, occupying the core of the villus, are found spaces which, because of their white appearance after the absorption of fats, have been called *lac'teals*.

**Absorption of Foods.** — Food substances in solution pass by osmosis into the cells lining the villi. These cells are alive, and therefore have the power of selecting certain substances and rejecting others. Once within the villi, the sugars and digested proteins pass through tiny blood vessels into larger vessels comprising the *portal circulation*. These pass to the liver, where, as we have seen, sugar is taken from the blood and stored as glycogen. From the liver, the food in the blood is carried to the heart, from there is pumped to the lungs, returns to the heart, and is pumped to the tissues of the body. A large amount of water and some salts also are absorbed through the walls of the stomach and intestine. The fats in the form of soaps and fatty acids pass into the cells lining the walls of the villi but are immediately changed back to fats, in which form they are found in the central spaces within the villi. Fats eventually reach the blood by way of the thoracic duct *without* passing through the liver.

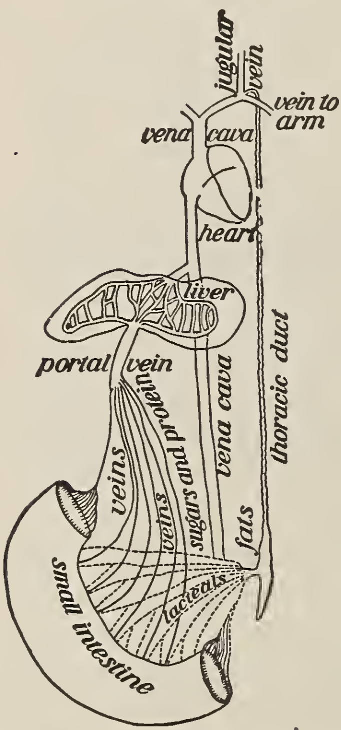



Diagram to show how the nutrients reach the blood.

**Large Intestine.** — The large intestine has somewhat the same structure as the small intestine, except that the diameter is greater and it has no villi. Considerable absorption, however, takes place through its walls as the mass of food and refuse material is slowly pushed along by the muscular walls.

In this portion of the intestine live millions of bacteria,

some of which manufacture poisonous substances from the foods on which they live. These substances are easily absorbed through the walls of the large intestine, and passing into the blood, cause headaches or sometimes serious trouble. Hence it follows that the lower bowel should be emptied of this matter at least once a day. Constipation is one of the serious evils the American people have to deal with, and it is largely brought about by the artificial life which they lead, with its lack of sufficient exercise, fresh air, and sleep.

**Vermiform Appendix.** —At the point where the small intestine widens to form the large intestine, a baglike pouch is formed. From one side of this pouch is given off a small tube about four inches long, closed at the lower end. This tube, the function of which in man is unknown, is called the *vermiform appendix*. It has come to have unpleasant notoriety in late years, as the seat of serious inflammation. It often becomes necessary to remove the appendix in order to prevent this inflammation from spreading to the surrounding tissues.

**Hygienic Habits of Eating; the Causes and Prevention of Dyspepsia.** — From the contents of the foregoing chapter it is evident that the object of the process of digestion is to break up solid food so that it may be absorbed to form part of the blood. Any habits we may form of thoroughly chewing our food will aid in this process. Much of the distress known as dyspepsia is due to eating too rapidly with consequent lack of proper mastication of food. The message of Horace Fletcher in bringing before us the need of proper mastication of food and the attendant evils of overeating is one which we cannot afford to ignore. It is a good rule to go away from the table feeling hungry. Eating too much overtaxes the digestive organs and prevents their working to the best advantage. Still another cause of dyspepsia is eating when in a fatigued condition. It is always a good plan to rest a short time before eating, especially after any hard manual work. Eating between meals is also condemned by physicians because it calls the blood to the digestive organs at a time when it should be in other parts of the body.

**Effect of Alcohol on Digestion.** — It is a well-known fact that alcohol extracts water from tissues with which it is in contact. This fact works much harm to the interior surface of the food tube, especially the walls of the stomach, which in the case of a hard drinker are likely to become irritated and much toughened. In small amounts alcohol stimulates the secretion of the salivary and gastric glands, and thus seems to aid in digestion. It is doubtful, however, whether this aid is real.

Experiments on dogs performed by Chittenden show that alcohol retards digestion. He fed dogs on meat with water and then on meat with very dilute alcohol. The meat with alcohol took on the average about 25 minutes longer to digest.

**Summary.** — The organs of digestion form a tube, the walls of which are lined with digestive glands. Muscles are also found in the walls of the food tube; they cause an almost constant churning movement in the stomach, and are also responsible for the movements known as *peristalsis* in the small intestine.

Digestion is a process which causes insoluble food to pass through a series of changes so that it becomes simpler in structure and will pass through the walls of the food tube. Digestion is brought about by the action of various *enzymes*, each of which acts upon a given substance.

Absorption takes place largely in the small intestine, where many fingerlike projections called *villi* take up the various food substances and pass them into the blood. Fats are not taken directly into the blood but are first passed through tubes called the *lacteals*. Eventually they reach the blood through the thoracic duct.

**Problem Questions.** — 1. How is digestion brought about?

2. What is an enzyme? How is it made? Name some enzymes and give their functions.

3. Discuss the teeth as to function, structure, and care.

4. What is the function of the tongue in digestion? of the salivary glands?

5. What are the functions of the stomach? How are they accomplished?

6. What are hormones and what do they do?

7. Why is the pancreas considered the most important digestive gland?

8. What is glycogen and where is it made?

9. How and where is food absorbed?

10. What effect does alcohol have on digestion?

### Problem and Project References

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## XXVI. THE BLOOD AND ITS CIRCULATION

**Problem.** *To study the composition of the blood.* (*Laboratory Manual, Prob. XLVIII; Laboratory Problems, Probs. 198 to 200.*)

**Functions of the Blood.** — The chief function of the digestive tract is to change insoluble foods to such form that they can be absorbed through the walls of the food tube and become part of the blood. The blood in turn carries these foods in solution to the cells of the body and removes waste materials from them. It supplies tissues with oxygen and removes carbon dioxide. Heat produced by the oxidation of foods is carried by the blood from the internal organs to the surface of the body, where it is given off. Thus the blood regulates the temperature in different parts of the body.

In addition to these important uses the blood carries two kinds of substances of vital importance to the body, the *hormones* or regulative substances already spoken of, and the various *antibodies* or disease-resisting substances manufactured by the blood, as the *agglu'tinins, precip'itins* and *hæmoly'sins.*

If we examine under the microscope a drop of blood taken from the frog or man, we find it made up of a fluid called *plasma* and two kinds of bodies, the so-called *red corpuscles* and *colorless corpuscles,* floating in this plasma.

**Composition of Plasma.** — The plasma of human blood (when chemically examined) is found to be about 90 per cent water. It contains also amino-acids, some sugar, fat, and mineral material. It is, then, the medium which holds the fluid food that has been absorbed from within the intestine. When the blood returns from the tissues where the food is oxidized, the plasma brings back with it to the lungs most of the carbon dioxide liberated when oxidation took place. Blood returning from the tissues of the body has from 45 to 50 c.c

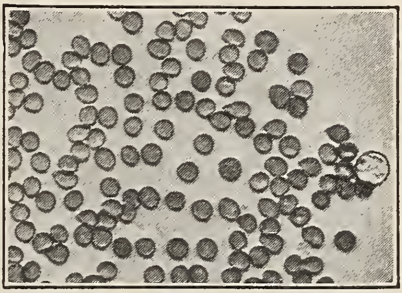
of carbon dioxide to every 100 c.c. (See Chapter XXVII.) *Fibrin'ogen* and some waste products to be spoken of later, are also found in the plasma. It also contains the hormones and the antibodies.

**Suggested Experiment: Clotting of Blood.** — If fresh beef blood is allowed to stand over night, it will be found to have separated into two parts, a dark red, almost solid *clot* and a thin, straw-colored liquid called *serum*. Serum is made up of about 90 per cent water, 8 to 9 per cent protein, and from 1 to 2 per cent sugars, fats, and mineral matter. In these respects it very closely resembles the fluid food that is absorbed from the intestines.

If another jar of fresh beef blood is poured into a pan and briskly whipped with a bundle of little rods (or with an egg beater), a stringy substance will be found to stick to the rods. This, if washed carefully, is seen to be almost colorless. Tested with nitric acid and ammonia, it is found to contain a protein substance called *fibrin*.

Blood plasma, then, is made up of serum, a colorless fluid, and *fibrinogen*, or the fibrin in a fluid state. Under abnormal conditions, such as removal from the blood vessels, a complicated series of changes is started which ends with the formation of the tiny threads of fibrin in the blood, and the subsequent formation of a clot. A clot is simply a mass of fibrin threads with a large number of corpuscles tangled within. The clotting of blood is of great physiological importance, as it checks the flow of blood; otherwise we might bleed to death from the smallest wound.

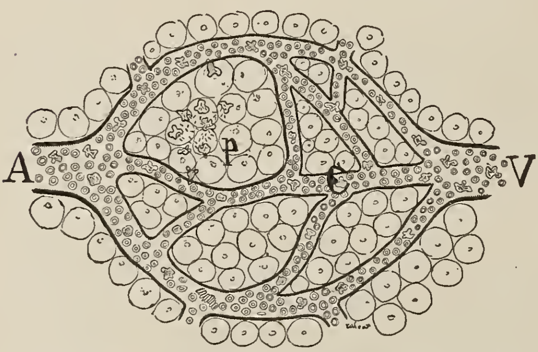
In blood within the circulatory system of the body, the fibrin is in the fluid form called fibrinogen. An enzyme, acting upon this fibrinogen under certain conditions, causes it to change to an insoluble form, the fibrin of the clot.



Human blood, highly magnified.

**The Red Blood Corpuscle; its Structure and Functions.** — The red corpuscle in the blood of the frog is a true cell of disk-like form. The red corpuscle of man, however, lacks a nucleus. Its form is that of a biconcave disk. So small and so numerous are these corpuscles that over five million are found in a drop of normal blood.

The color, which is found to be a dirty yellow when separate corpuscles are viewed under the microscope, is due to a protein material called *hæmoglo'bin.* Hæmoglobin contains a large amount of iron. It has the power of uniting very readily with oxygen whenever that gas is abundant, and of giving it up to the surrounding media when oxygen is present in smaller amounts than in the corpuscle. This carrying of oxygen is the most important function of the red corpuscle, although the red corpuscle removes part of the carbon dioxide also from the tissues on its return to the lungs. The taking up of oxygen is accompanied by a change in color of the mass of corpuscles from a dull red to a bright scarlet. The red corpuscles arise as small cells in the red marrow of the living bones but soon lose their nuclei and are passed into the blood stream. After they are worn out it is believed that they are destroyed in the spleen and liver.

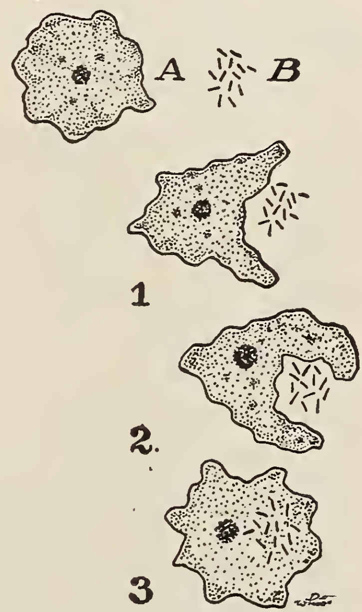


Colorless corpuscles *p* in the tissues outside the blood vessels. *A*, small artery; *C*, capillaries; *V*, small vein. Highly magnified.

**The Colorless Corpuscle; Structure and Functions.** — A colorless corpuscle is a cell irregular in outline, the shape of which is constantly changing. These corpuscles are somewhat larger than the red corpuscles, but less numerous, there being about one colorless corpuscle to every seven hundred red ones. The colorless corpuscles have the power of movement, and can work their way between the cells in the walls of the blood vessels and wander into the tissues outside. There appear to be several varieties of colorless corpuscles; some are made in the lymph glands and others in the red marrow of bone. Their ultimate fate is uncertain, except in the case described in the next paragraph.

A Russian zoölogist, Metschnikoff, after studying a number of simple animals, such as medusæ and sponges, found that in such animals some of the cells lining the inside of the food cavity take up or ingulf minute bits of food just as amœbæ do.

Later, this food is changed into the protoplasm of the cell. Metschnikoff believed that the colorless corpuscles of the blood have somewhat the same function, and he later proved this to be true. Like the cells in the simple animals, the colorless corpuscles feed by ingulfing their prey. This fact has a very important bearing on the relation of colorless corpuscles to certain diseases caused by bacteria within the body. If, for example, a cut becomes infected by bacteria, inflammation may set in. Colorless corpuscles at once surround the spot and attack the bacteria. It has been found, however, that bacteria are not "eaten" until they are first bathed with a chemical substance known as an *op′sonin.* The presence of these opsonins in the blood makes the bacteria attractive. If the bacteria are few in number, they are quickly destroyed by the colorless corpuscles, which are known as *phag′ocytes.* If bacteria are present in great quantities, they may prevail and kill the phagocytes by poisoning them. The dead bodies of the phagocytes thus killed are found in the pus which accumulates in infected wounds. In case of a possible infection we must come to the aid of the colorless corpuscles by washing the wound with some suitable antiseptic, as hydrogen peroxide.



A colorless corpuscle *A* ingulfing germs *B*.

**The Disease-resisting Mechanism of the Blood.** — It is common knowledge that some of us "take" catching or infectious diseases more easily than others. Some fortunate people are *immune* to certain diseases or do not take them at all. Such immunity is brought about by the blood when a certain substance is present in it and attacks and destroys bacteria by chemical action or by the work of the colorless corpuscles. This is an extremely complicated process which is probably caused by different substances which act specifically upon different kinds of bacteria. Just as each disease is caused by a

specific kind of germ, producing a specific kind of poison, so the blood appears to produce specific antibodies to fight these specific germs.

**The Amount of Blood and its Distribution.** — Blood forms, by weight, about one thirteenth of the human body. Its distribution varies somewhat according to the position assumed by the body, and the amount of undigested food in the stomach and intestines. Normally, about one half of the blood of the body is found in or near the organs lying in the body cavity, about one fourth in the muscles, and the rest in the heart, lungs, large arteries, and veins.

**Blood Temperature.** — The temperature of blood in the human body is normally about 98.5° Fahrenheit, although the temperature drops almost two degrees after we have gone to sleep at night. It is highest about 5 P.M. and lowest about 4 A.M. In fevers, the temperature of the body sometimes rises to 107° or higher; but unless this temperature is soon reduced, death follows. Any considerable drop in temperature below the normal also would mean death. Body heat, as we know, results from the oxidation of food; the constant circulation of blood keeps the temperature nearly uniform in all parts of the body. The body temperature may be from two to three degrees higher immediately after violent exercise. Why?

**Cold-blooded Animals.** — In animals which are called cold-blooded, the blood has no fixed temperature, but varies with the temperature of the medium in which the animals live. Frogs, in the summer, may sit for hours in water with a temperature of almost 100°. In winter, they often endure freezing so that the blood and lymph within the spaces under the loose skin are frozen into ice crystals. Such frogs, if thawed out carefully, will live. This change in body temperature is evidently an adaptation to the mode of life.

**Circulation of the Blood in Man.** — The blood is the carrying agent of the body, and conveys materials from one part of the human organism to another. This it does by means of the organs of circulation — the heart and the blood vessels. The blood vessels include *arteries* which carry blood away from the heart, *veins* which bring blood back to the heart, and *capillaries*

which connect the arteries with the veins. The organs of circulation thus form a system of connected tubes through which the blood flows in a continuous stream.

**The Heart; Position, Size, Protection.** — The heart is a cone-shaped muscular organ about the size of the fist. It is located immediately above the diaphragm, and lies so that the muscular apex which points downward, moves while beating against the fifth and sixth ribs, just a little to the left of the midline of the body. This fact gives rise to the notion that the heart is on the left side of the body. The heart is surrounded by a loose membranous bag called the *pericardium,* the inner lining of which secretes a fluid which surrounds the heart. When, for any reason, the pericardial fluid is not secreted, inflammation arises in that region. Do you know why?

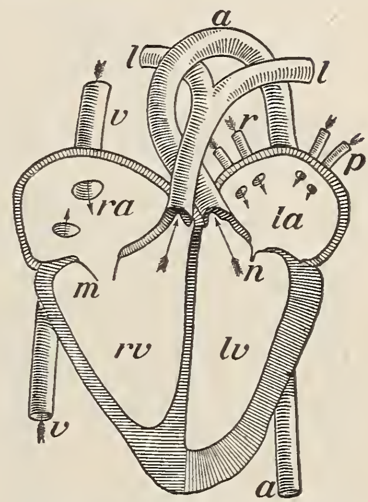
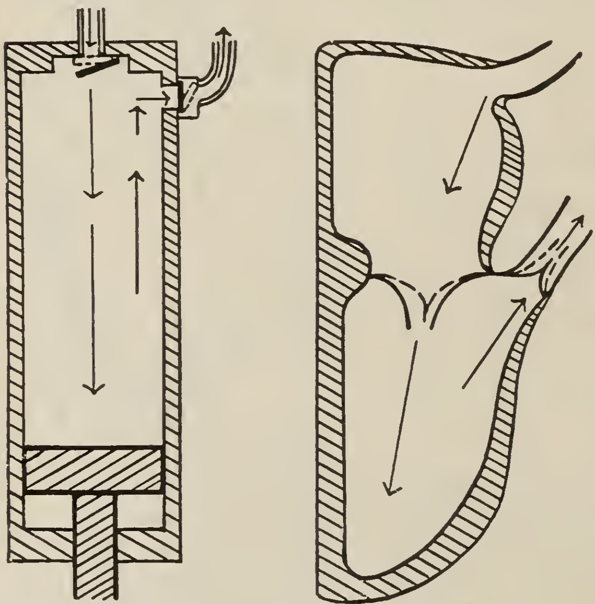


Diagram showing the front half of the heart cut away: *a*, aorta; *l*, pulmonary arteries; *la*, left auricle; *lv*, left ventricle; *m*, tricuspid valve open; *n*, bicuspid or mitral valve closed; *p* and *r*, pulmonary veins; *ra*, right auricle; *rv*, right ventricle; *v*, *v*, venæ cavæ. Arrows show direction of circulation.

**Internal Structure of the Heart.** — If we should cut open the heart of a mammal down the midline, we could divide it into a right and a left side, and show that each side has no internal connection with the other. Each side is made up of a thin-walled portion with a rather large internal cavity, the *auricle,* and a smaller chamber with heavy muscular walls, called the *ventricle.* The auricles occupy the base of the cone-shaped heart; the ventricles, the apex. Communication between auricles and ventricles is regulated by little flaps of muscle called *valves.* The auricles receive blood from the veins and pass it on to the ventricles. The ventricles pump the blood into the arteries. From the left ventricle out through the *aor'ta* blood passes to all parts of the body. From the right ventricle the *pul'monary arteries* carry blood to the lungs. The openings to the arteries are guarded by three half-moon-shaped flaps, which open so as to allow

blood to pass away from the ventricle, and close to prevent its going back when the muscles relax.

**The Heart in Action.** — The heart is constructed on the same plan as a force pump, the valves preventing the reflux of blood into the auricles after it is forced out of the ventricles. Blood enters the auricles from the veins because the muscles of that part of the heart relax; this allows the space within the auricles to fill. Almost immediately the muscles of the ventricles relax, thus allowing blood to pass into the chambers within the ventricles. Then, after a short pause, during which time the muscles of the heart are resting, a wave of muscular contraction begins in the auricles and ends in the ventricles, with a sudden strong contraction which forces the blood out into the arteries. Blood is kept from flowing backwards by the valves, and is thus forced to pass into the arteries upon the contraction of ventricle walls.



The heart is a force pump; prove it from these diagrams.

**The Course of the Blood in the Body.** — Although the two sides of the heart are separate and distinct from each other, yet every drop of blood that passes through the right heart soon passes also through the left heart. There are two distinct systems of circulation in the body. The *pulmonary circulation* takes the blood through the right auricle and right ventricle, to the lungs, and passes it back to the left auricle. This is a relatively short circulation, in which the blood receives oxygen in the lungs and gives up its carbon dioxide. The greater circulation is known as the *system'ic circulation;* in this system

the blood leaves the left ventricle through the great dorsal aorta. A large part of the blood passes directly to the muscles; some of it goes to the nervous system, kidneys, skin, and other organs of the body. It gives up food and oxygen, and receives the waste products of oxidation while passing through the capillaries, and then returns to the right auricle through two large vessels known as the *venæ cavæ*. It requires from twenty to thirty seconds only for the blood to make the complete circulation from the ventricle back again to the starting point. This means that the entire volume of blood in the human body passes three or four thousand times a day through the various organs of the body.

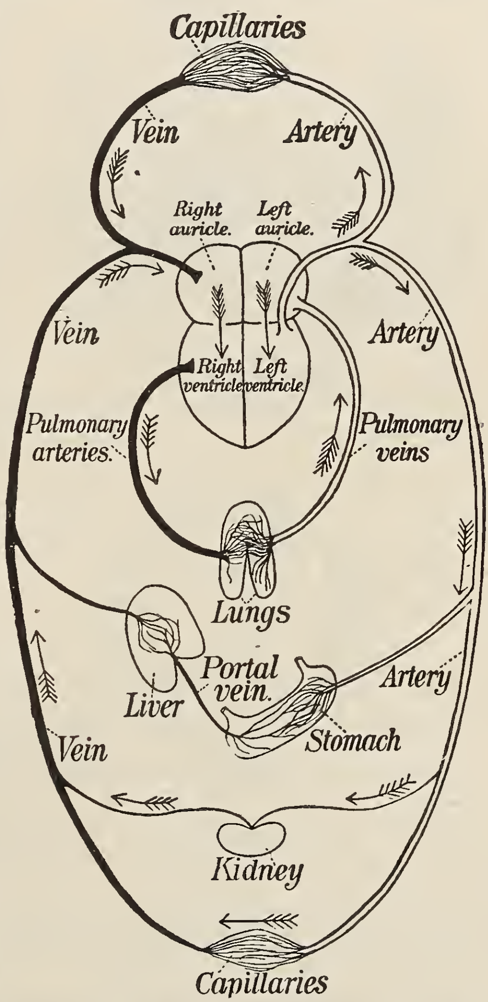


Diagram of the circulation of blood in a mammal.

**Portal Circulation.** — Some of the blood, on its return to the heart, passes by an indirect path to the walls of the food tube, absorbs food, and goes to the liver. Here the veins which carry the blood (called the portal veins) break up into capillaries around the cells of the liver. We have already learned that the liver is a great storehouse of animal sugar called *glycogen*. This glycogen is a food that may be easily oxidized to release energy, and is stored for that purpose. The sugar that becomes glycogen is carried to the liver directly from the walls of the stomach and intestine, where it has been absorbed from the food there contained. From the liver, blood passes directly to the right auricle. The *portal circulation* consists of three veins which carry blood from the stomach and intestine to the liver, and is the only part of the circulation where the blood passes through two sets of capillaries, before going to the heart — one set in the walls of the stomach and intestine, and the other in the liver.

**Problem.** — *A study of the circulation of the blood. (Laboratory Manual, Prob. XLIX; Laboratory Problems, Probs. 201 to 206.)*

**Circulation in the Web of a Frog's Foot.** — If the web of the foot of a live frog or the tail of a tadpole is examined under the compound microscope, a network of blood vessels will be seen. In some of these the corpuscles are moving rapidly and in spurts; these are *arteries.* The arteries lead into a network of smaller vessels or *capillaries* hardly greater in diameter than the width of a single corpuscle. The capillaries unite into larger *veins* in which the blood moves regularly. This illustrates the condition in any tissue of man where the arteries break up into capillaries which unite to form veins.

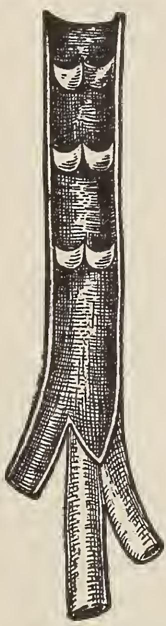
Capillary circulation in the web of a frog's foot, as seen under the compound microscope.

**Structure of the Arteries.** — A distinct difference in structure exists between the arteries and the veins in the human body. The arteries, because of the greater strain received from the blood which is pumped from the heart, have thicker muscular walls, and in addition are very elastic.

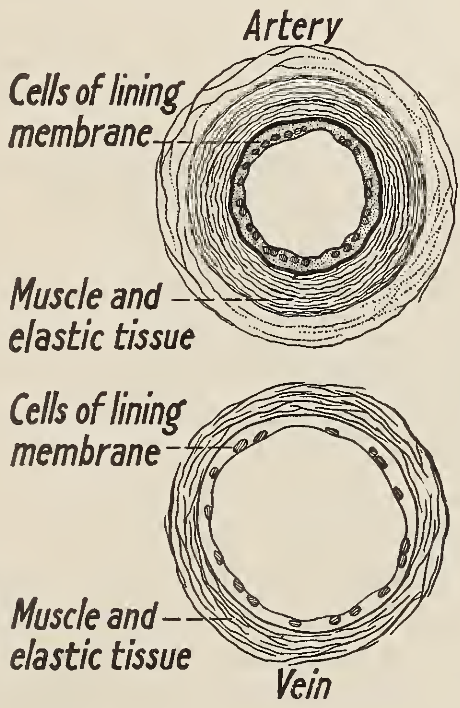
**Cause of the Pulse.** — The *pulse,* which can easily be detected by pressing the large artery in the wrist or the small one in front of and above the external ear, is caused by the gushing of blood through the arteries after each pulsation of the heart. As the large arteries pass away from the heart, and divide, the diameter of each artery becomes smaller. At the very end of their course, these arteries are so small as to be almost microscopic in size and are very numerous. There are so many that if they were placed together, side by side, their united diameter would be much greater than the diameter of the large artery (*aorta*) which passes blood from the left side of the heart. This fact is of very great importance, for the force of the blood as it gushes through the arteries becomes very much less when it reaches the smaller vessels. This gushing movement is quite lost when the capillaries are reached, first, because there is so much more space for the blood to fill, and secondly, because there is considerable friction caused by the very tiny diameter of the capillaries.

**Capillaries.** — The capillaries form a network of minute tubes everywhere in the body, but especially near the surface and in the lungs. It is through their walls that the food and oxygen pass to the tissues, and carbon dioxide is given up to the plasma. They form the connection between arteries and veins that completes the system of circulation of blood in the body.

**Function and Structure of the Veins.** — If the arteries are supply pipes which convey fluid food to the tissues, then the



Valves in a vein. Notice the thin walls of the vein.




Cross section of artery and vein.

veins may be likened to drain pipes which carry away waste material from the tissues. Very numerous in the extremities and in the muscles and among other tissues of the body, they, like the branches of a tree, become larger as they unite with each other on their way back to the heart.

If the wall of a vein is carefully examined, it will be found to be neither so thick nor so tough as an artery wall. When empty, a vein collapses; the wall of an artery holds its shape. If you hold your hand down for a little time and then examine

it, you will find that the veins, which are relatively much nearer the surface than are the arteries, appear to be very much knotted. This appearance is due to the presence of tiny valves within the veins. These valves open in the direction of the blood current, but would close if the direction of the blood flow should be reversed (as in case a deep cut severed a vein). As the pressure of blood is much less in the veins than in the arteries, the valves aid in keeping the flow of blood in the veins toward the heart. The higher pressure in the arteries and the suction in the veins (caused by the enlargement of the chest cavity in breathing) are the chief factors which cause a steady flow of blood through the veins in the body.

***Problem.*** *To study some changes in the composition of the blood. (Laboratory Manual, Prob. L; Laboratory Problems, Prob. 197.)*

**The Ductless Glands and their Secretions.** — One of the greatest discoveries of modern physiology is that many groups of gland cells give off to the blood internal secretions that play extremely important parts in the life of man. Such glands are the *suprare'nal bodies* located just above the kidneys, the *thy'roid* and *parathy'roid* glands in the neck, certain cells of the reproductive organs, and probably various other glands such as the pancreas and liver. An example of the lack of some internal secretions is seen in *cre'tinism,* a kind of idiocy. Here it is found that the disease is caused by a lack of internal secretions from the thyroid gland. If extracts of sheep's thyroid are fed to children who show cretinism they soon recover their normal condition. The suprarenal glands throw into the blood substances which act as an emergency hormone and stimulate the body to increased activity when this is necessary. An abnormal condition of the suprarenals brings about a disease known as Addison's disease. The gland cells of the reproductive organs give the characteristics to the body which mark the differences in voice, average height and weight, etc., between boys and girls. Our knowledge of the work of the ductless glands is just beginning and future study will doubtless answer many interesting questions.

**Function of Lymph.** — Different tissues and organs of the body are traversed by a network of tubes which carry the blood. Inside these tubes is the blood, consisting of a fluid plasma, the colorless corpuscles, and the red corpuscles. Outside the blood tubes, in spaces between the cells which form tissues, is found another fluid, which is in chemical composition very much like plasma of the blood. This is the *lymph.* It is, in fact, fluid food in which some colorless amœboid corpuscles are found. Blood gives up its food material to the lymph by passing it through the walls of the capillaries. The lymph surrounds the tissue cells and supplies them with food.

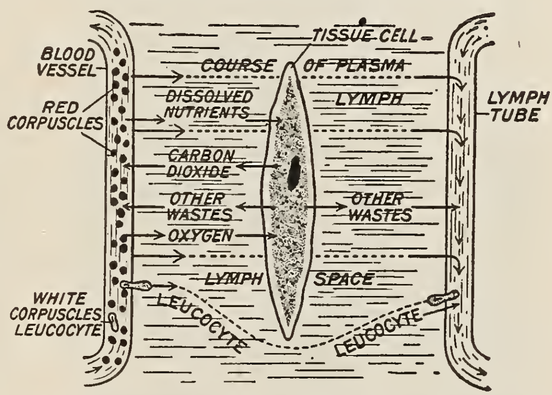
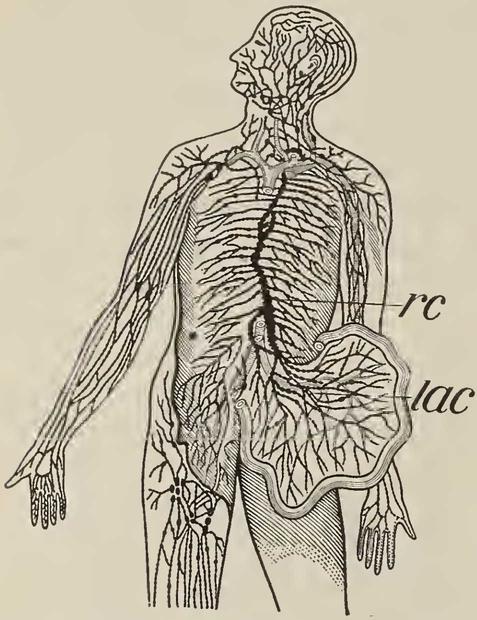



Diagram showing the exchange between blood and the cells of the body.

Some of the colorless corpuscles from the blood make their way out between the cells forming the walls of the capillaries, and enter the lymph. *Lymph, then, is practically blood plasma plus some colorless corpuscles. It acts as the medium of exchange between the blood proper and the cells in the tissues of the body.* The food supply thus brought enables the cells of the body to grow, the fluid food being changed to the protoplasm of the cells. By means of the oxygen passed over by the lymph, oxidation may take place within the cells. Lymph not only gives food to the cells of the body, but also takes away carbon dioxide and other waste materials, which are ultimately passed out of the body by means of the lungs, skin, and kidneys.

**Lymph Vessels.** — The lymph is collected from the various tissues of the body by means of a number of very thin-walled tubes, which are at first very tiny, but after repeated connection with other tubes ultimately unite to form large ducts. These lymph ducts are provided, like the veins, with valves. The pressure of the blood within the blood vessels forces continually more plasma into the lymph; thus a slow current is maintained from the lymph spaces toward the veins. On its course the lymph passes through many collections of gland cells, the *lymph glands.* In these glands impurities appear to be removed and some of the colorless corpuscles made.

The lymph ultimately passes into a large tube, the *thorac'ic duct,* which flows upward near the ventral side of the spinal column, and empties into the large subclavian vein in the left side of the neck. Another smaller lymph duct enters the right subclavian vein.




The lymph vessels: the dark spots are lymph glands; *lac*, lacteals; *rc*, thoracic duct.

**The Lacteals.** — We have already found that part of the digested food (chiefly carbohydrates, amino-acids, salts, and water) is absorbed directly into the blood through the walls of the villi and carried to the liver. Fat, however, is passed into the spaces in the central part of the villi, and from there into other spaces between the tissues, known as the *lacteals.* The lacteals form the most direct course for the fats to reach the blood. The lacteals and lymph vessels have in part the same course. It will be thus seen that lymph at different parts of its course would have a very different composition.

**The Nervous Control of the Heart and Blood Vessels.** — Although the muscles of the heart contract and relax without our being able to stop them or force them to go faster, yet in cases of sudden fright, or after a sudden blow, the heart may stop beating for a short interval. This shows that the heart is under the control of the nervous system. Two sets of nerve fibers, both of which are connected with the central nervous system, pass to the heart. One set of fibers accelerates, the other slows or inhibits, the heartbeat. The arteries and veins are also under the control of the sympathetic nervous system. This allows a change in the diameter of the blood vessels. Thus, blushing is due to a sudden rush of blood to the surface of the body, caused by an expansion of the blood vessels in that region. The blood vessels of the body are always full of blood. This results from an automatic regulation of the diameter of the blood vessels by a part of the nervous system called the *vasomo'tor nerves.* These nerves act upon the muscles in the walls of the blood vessels. In this way, each vessel adapts itself to the amount of blood in it at a given time. After a hearty meal, a large supply of blood is needed in the walls of the stomach and intestines; therefore, the arteries going to this region are dilated so as to receive an extra supply. When the brain performs hard work, blood is supplied in the same manner to that region. Hence, one should not study or do mental work immediately after a hearty meal, for blood

will be drawn to the brain, leaving the digestive tract with an insufficient supply. Indigestion may follow as a result.

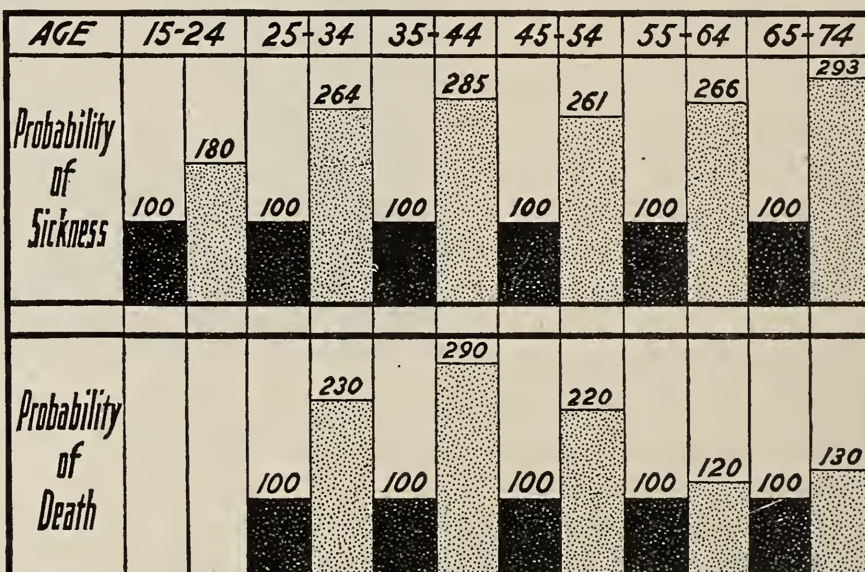
**Effect of Exercise on the Circulation.** — It is a fact familiar to all that the heart beats more violently and more quickly when we are doing hard work than when we are resting. Count your own pulse when sitting quietly, and then again after some brisk exercise in the gymnasium. Exercise in moderation is of undoubted value, because it sends more blood to those parts of the body where increased oxidation is taking place as the result of the exercise. The best forms of exercise are those which give work to as many muscles as possible — walking, out-of-door sports, any exercise that is not violent. Exercise should not be attempted immediately after eating, as this causes a withdrawal of blood from the digestive glands and from the walls of the food tube to the muscles of the body. Neither should exercise be continued after one is tired, as poisons are then formed in the muscles, which cause *fatigue.* Remember that hard work given to the heart by extreme exercise may injure it, causing possible trouble with the valves.

Stopping flow of blood from an artery by applying a tight bandage (ligature) between the cut and the heart.

**Treatment of Cuts and Bruises.** — Blood which oozes slowly from a cut will usually be checked by the natural means of the formation of a clot. A cut or bruise should, however, be washed in a weak solution of carbolic acid or some other antiseptic and kept covered with clean gauze in order to prevent bacteria from obtaining a foothold on the exposed flesh. If blood, issuing from a wound, is bright red in color and gushes in distinct pulsa-

tions, an artery has been severed. To prevent the flow of blood, a tight bandage must be bound on between the cut and the heart. A handkerchief tied with a knot placed over the artery may stop bleeding if the cut is on one of the limbs. If this does not serve, then insert a stick in the handkerchief and twist it so as to make the pressure around the limb still greater. Thus we may close the artery until the doctor arrives and he may sew up the injured blood vessel. If a vein is cut the blood flows out in a steady stream. When the loss of blood is great it may be checked by a tight bandage on the side of the cut, away from the heart.

**The Effect of Alcohol upon the Blood.** — It has recently been discovered that alcohol has an extremely injurious effect




A comparison of the chances of illness and death in drinkers and non-drinkers. For each age shown, the light shaded area represents the probability of sickness and death for drinkers, as compared with the dark area marked 100 for non-drinkers. For example, if among non-drinkers aged 15 to 24 years 100 out of 8,200 are sick, then the diagram indicates that among drinkers of the same age probably 180 out of 8,200 would be sick.

upon the colorless corpuscles of the blood, lowering their ability to fight disease germs to a marked degree. This is clearly shown in a comparison of deaths from certain infectious diseases of drinkers and of abstainers, the percentage of mortality being much greater in the former.

**The Effect of Alcohol on the Circulation.** — Alcoholic drinks affect the very delicate adjustment of the nervous centers controlling the blood vessels and heart. Even very dilute alcohol relaxes the muscles of the tiny blood vessels, consequently more blood is allowed to enter them, and, as the small vessels are usually near the surface of the body, the habitual redness seen in the face of hard drinkers is the ultimate result. The walls of the arteries become hardened and lose their elasticity when alcohol is in the system.

**Summary.** — Blood is really liquid food containing two types of cells, red and colorless corpuscles. The former are oxygen carriers, the latter protect the body from disease.

Blood is kept in circulation within arteries, capillaries, and veins, by a double force pump called the heart. The fluid part of the blood with its load of food and gases, gets through the walls of the smallest blood vessels and bathes the individual cells of the body so that they may take up this food and oxygen passed in to them. They in turn give up wastes and carbon dioxide to the lymph, as this fluid is called.

**Problem Questions.** — 1. Is the blood a tissue? Why?

2. What is the function of the red corpuscles? of colorless corpuscles?

3. What is the composition of plasma? How do you account for this?

4. How does lymph differ from plasma?

5. Prove that the heart is a force pump.

6. Compare the short and long circulations in the body.

7. How do cells get food and get rid of wastes? How do they "breathe"?

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# XXVII. RESPIRATION AND EXCRETION

***Problem.*** *A study of the organs and the process of respiration to determine —*

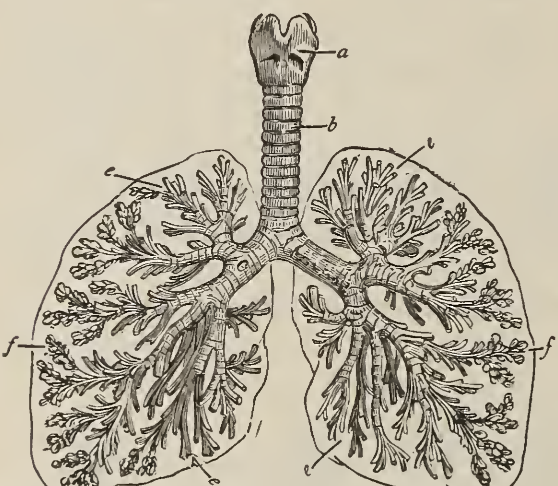
(*a*) *Organs of respiration in frog.*

(*b*) *Mechanics of respiration.*

(*c*) *Process of respiration in the lungs.*

(*Laboratory Manual, Prob. LI; Laboratory Problems, Probs. 207 to 213.*)

**Necessity for Respiration.** — We have seen that plants and animals need oxygen in order that the life processes may go on. Food is oxidized to release energy, just as coal is burned to give heat to run an engine. As a draft of air is required to make fire under the boiler, so, in the human body, oxygen must be given so that foods in the tissues may be oxidized to release energy used in growth. This oxidation takes place in the cells of the body, be they part of a muscle, a gland, or the brain. *The red blood corpuscles in their circulation to all parts of the body are the agents which convey oxygen to those places in the body where it will be used. Respiration is taking in oxygen and giving off carbon dioxide by the cells.*




Air passages in the human lungs: *a*, larynx; *b*, trachea (or windpipe); *c*, *d*, bronchi; *e*, bronchial tubes; *f*, cluster of air cells.

**The Organs of Respiration in Man.** — We have alluded to the fact that the lungs are the organs which give oxygen to the blood and take from it carbon dioxide. The course of air

passing from the outside to the lungs in man is much the same as that in the frog. Air passes through the nostrils, the pharynx, the glottis, and into the windpipe. This cartilaginous tube, the top of which may easily be felt as the Adam's apple of the throat, divides into two *bronchi* (brŏng′kī), each of which goes to a lúng. The bronchi within the lungs break up into a great number of smaller *bronchial tubes*, which divide somewhat like the small branches of a tree, and end in air sacs. This branching increases the surface of the air tubes within the lungs.

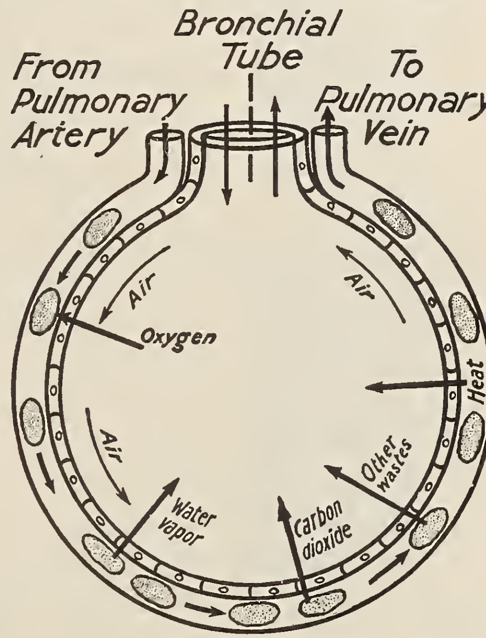



Diagram to show what the blood gains and loses in one of the air sacs of the lungs.

There are several adaptations which should be noted at this point. The folds in the inside of the nose passage warm and moisten the air somewhat before it enters the bronchi. The hairs in the nose passage act as a strainer which keeps most of the dust and germs out from the lungs. Then the bronchial tubes, indeed all the air passages, are lined with cilia, which are constantly in motion, beating with a quick stroke toward the mouth. Hence, if any foreign material should get into the windpipe or bronchial tubes, it would be pushed upward by the action of the cilia. It is by means of cilia that phlegm is raised into the throat. Such action is of great importance, as it prevents the air passages from filling with foreign matter. The bronchial tubes end in very minute air sacs — little pouches having elastic walls — into which air is taken when we inspire or take a deep breath. In the walls of the air sacs are numerous capillaries. *It is through the very thin walls of the air sacs that an interchange of gases takes place which results in the blood giving up carbon dioxide and taking up oxygen.*

**The Pleura.** — The lungs are covered with a thin elastic

membrane, the *pleura,* which forms a bag in which the lungs are hung. Between the walls of the bag and the lungs is a space filled with lymph. By this means the lungs are prevented from rubbing against the walls of the chest.

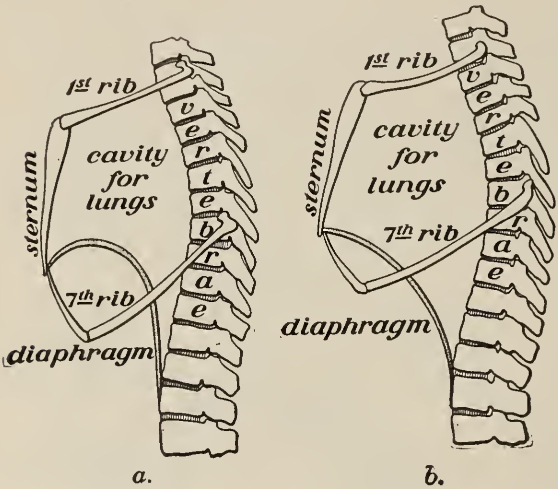
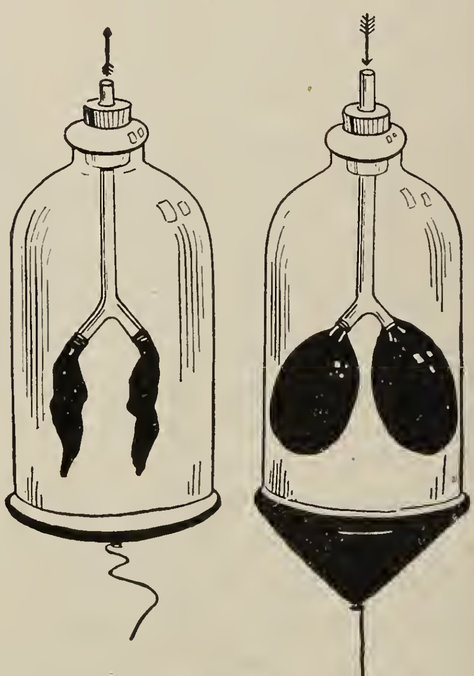


Diagram showing portion of diaphragm and ribs in (*a*) expiration; (*b*) inspiration.

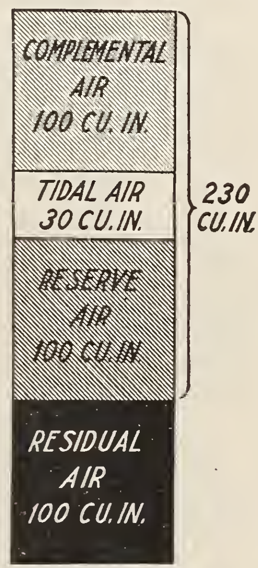
**Breathing.** — In every full breath there are two distinct movements, inspiration (taking air in) and expiration (forcing air out). In man an inspiration is produced by the contraction of the muscles between the ribs together with the contraction of the diaphragm, the muscular wall forming the floor of the chest cavity; this results in pulling down the diaphragm and pulling upward and outward the ribs, thus making the space within the chest cavity larger. The lungs, which lie within this cavity, are filled by the air rushing into the larger space thus made. An expiration is simpler than an inspiration, for it requires no muscular effort; the muscles relax, the breastbone and ribs sink into place, while the diaphragm returns to its original position and the air is pushed out.


Apparatus to show the mechanics of breathing.

**Experiment to Illustrate the Mechanics of Breathing.** — A piece of apparatus which illustrates to a degree the mechanics of breathing may be made as follows: Attach a string to the

middle of a piece of sheet rubber. Tie the rubber over the large end of a bell jar. Pass a glass Y tube through a rubber stopper. Fasten two small toy balloons to the branches of the tube. Close the small end of the jar with the stopper. Adjust the tube so that the balloons shall hang free in the jar. If now the rubber sheet is pulled down by means of the string, the air pressure in the jar is reduced and the toy balloons within expand, owing to the air pressure down the tube. When the rubber is allowed to go back to its former position, the balloons collapse.

**Rate of Breathing and Amount of Air Breathed.** — During quiet breathing, the rate of inspiration is from fifteen to eighteen times per minute; this rate depends largely on the amount of physical work performed. About 30 cubic inches of air are taken in and expelled during the ordinary quiet respiration. The air so breathed is called *tidal air.* In a "long breath," we take in about 100 cubic inches in addition to the tidal air. This is called *complemental air.* By means of a forced expiration, it is possible to expel from 75 to 100 cubic inches more than tidal air; this air is called *reserve* air. What remains in the lungs, amounting to about 100 cubic inches, is called the *residual air.* The value of deep breathing is seen by a glance at the diagram. When we take a full breath we ventilate the lung sacs which otherwise would not be used, and thus we clear the lungs of the reserve air with its accompanying load of carbon dioxide.




Amounts and proportions of complemental, tidal, reserve, and residual air in the breathing of an average adult man.

**Respiration under Nervous Control.** — The muscular movements which cause an inspiration are partly under the control of the will, but the movement is not wholly under our control. The nerve centers which govern inspiration are part of the sympathetic nervous system. Anything of an irritating nature in the trachea or larynx will cause a sudden expiration or cough. When a boy runs, the quickened respiration is due to the fact that oxygen is used up rapidly and a larger quantity of carbon dioxide is formed. This stimulates the nervous center which has control of respiration to greater activity, and quickened inspiration follows.

***Problem.*** *A study to determine the products of respiration. (Laboratory Manual, Prob. LII.)*

**Changes in Air in the Lungs.** — Air is much warmer after leaving the lungs than before it enters them. Breathe on the bulb of a thermometer to prove this. Expired air contains a considerable amount of moisture, as may be proved by breathing on a cold polished surface. This it has taken up in the air sacs of the lungs. The presence of carbon dioxide in expired air may be detected easily by the limewater test. Air such as we breathe out of doors contains, by volume: —

| | |
|---|---|
| Oxygen | 20.96 |
| Carbon dioxide | .04 |
| Nitrogen (and other gases) | 79 |

Air expired from the lungs contains : —

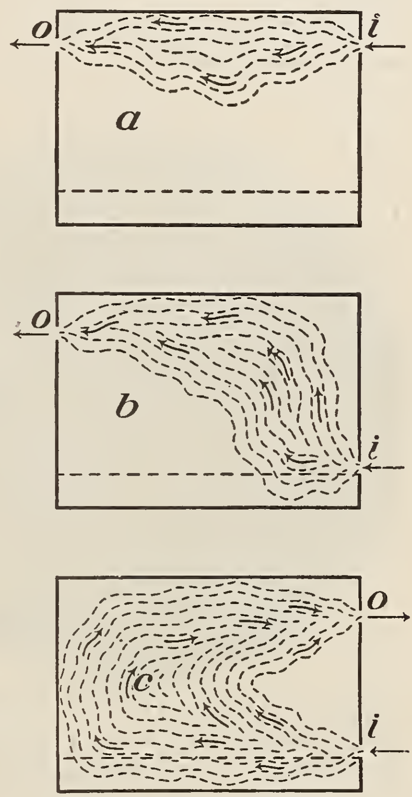
| | |
|---|---|
| Oxygen | 16.02 |
| Carbon dioxide | 4.38 |
| Water vapor | .60 |
| Nitrogen (and other gases) | 79 |

In other words, there is a loss of between four and five per cent oxygen, and nearly a corresponding gain in carbon dioxide, in expired air. There are also some other organic substances expelled. The volume of carbon dioxide given off is always a little less than the volume of oxygen taken in. This seems to show that some oxygen unites with some of the chemical elements in the body.

**Changes in the Blood within the Lungs.** — Blood, when leaving the lungs, is much brighter red than when entering them. The change in color is due to an absorption of oxygen by the *hæmoglobin* of the red corpuscle. The changes taking place in the blood are obviously the reverse of those that take place in the air in the lungs. *Blood in the capillaries within the lungs gains from four to five per cent of oxygen which the air loses. At the some time blood loses the four per cent of carbon dioxide which the air gains.* The blood, while in the lungs, gives off water vapor also, amounting to nearly one half a pint of water daily.

***Problem.*** *A study of ventilation. (Laboratory Manual, Prob. LIII; Laboratory Problems, Probs. 214 to 218.)*

**Need of Ventilation.** — Air in a living room or a schoolroom contains, besides dust and bacteria, carbon dioxide and other wastes given off from the human body. About 0.6 of a cubic foot of $CO_2$ is given off from the body every hour. In addition to this a large amount of moisture is given to the atmosphere of a crowded room and heat is dissipated from our bodies. We all know the discomfort felt in a crowded room with windows and doors closed. In order that the air bearing this heat, humidity, and carbon dioxide be removed and fresh air substituted it is necessary for us to ventilate our buildings.




Three ways of ventilating a room: *i*, inlet for air; *o*, outlet for air. Which is the best method of ventilation? Explain.

**How We Ventilate.** — In our homes, ventilation is usually accomplished by opening windows. A glance at the diagram shows three methods of ventilation. Which is the most adequate, and why? Too often people think they ventilate by opening a window either at the top or bottom only. This changes the air in only a very small part of the room. Fortunately for us the cracks under and around doors, windows, and baseboards, and fireplaces give us much natural ventilation. (See the diagram.)

Two thousand to three thousand cubic feet of air per hour is usually considered the average need of fresh air for each person. In schoolhouses or other public buildings, where many are in one room for a considerable period of time, it becomes necessary to have artificial methods of ventilation. This is usually accomplished by means of pumping warm air through ducts into a

room and sucking the stale air out through similar ducts. In some instances the air is passed through a filter or is washed to remove impurities. Often it passes in near the floor, sometimes from above. Describe the system used in your school and see if you can understand the science underlying its plan.

**Sweeping and Dusting.** — It is very easy to demonstrate the amount of dust in the air by looking at a beam of light in a darkened room. We have already proved that spores of mold and yeast exist in the air. That bacteria are also present may be proved by exposing a sterilized gelatin plate to the air in a schoolroom for a few moments.[1]

Plate culture exposed for five minutes in a school hall where pupils were passing to recitations. Each spot is a colony of bacteria or mold.

Many of the bacteria present in the air are active in causing diseases of the throat and lungs, such as diphtheria, membranous croup, tuberculosis, colds, bronchitis (inflammation of the bronchial tubes), and pneumonia (inflammation of the tiny air sacs of the lungs).

Dust, with its load of bacteria, will settle on any horizontal surface in a room not used for three or four hours. When a vacuum cleaner is not available dusting and sweeping should always be done with cloth and broom which are damp, otherwise the bacteria are simply stirred up, sent into the air, and allowed to settle down on the furniture and floor again. The proper watering of streets before they are swept is also an important factor in preserving health.

[1] Expose two sterilized dishes containing culture media; one in a room being swept with a damp broom, and the other in a room which is being swept in the usual manner. Note the formation of colonies of bacteria in each dish. In which dish does the greater number of colonies form? Why?

**Ventilation of Sleeping Rooms.** — Sleeping in close rooms is the cause of much illness. Beds should be placed so that a constant supply of fresh air is obtained without a direct draft. This may often be managed with the use of screens. Bedroom windows should be thrown open in the morning to allow free entrance of the sun and air, bedclothes should be washed frequently, and sheets and pillow covers often changed. Bedroom furniture should be simple, and but little drapery allowed in the room.

**Hygienic Habits of Breathing.** — Every one should form the habit of inspiring slowly and deeply and to the full capacity of the lungs upon going into the open air. A slow expiration should follow, forcing out as much air as possible. Breathe through the nose, thus warming the inspired air before it enters the lungs and chills the blood. Repeat this exercise several times every day. You will thus prevent certain of the air sacs which are not often used from becoming hardened and permanently closed.

**The Relation of Tight Clothing to Correct Breathing.** — It is impossible to breathe correctly unless the clothing is loose over the chest and abdomen. Tight corsets and tight belts prevent the walls of the chest and the abdomen from pushing outward and interfere with the drawing of air into the lungs. They may also result in permanent distortion of parts of the skeleton directly under the pressure. Other organs of the body cavity, as the stomach and intestines, may be forced downward, out of place, and in consequence they do not perform their work properly.

**Relation of Exercise to Deep Breathing.** — We have already seen that exercise results in the need of greater food supply, and hence a more rapid pumping of blood from the heart. With this comes need of more oxygen to allow oxidation which supplies the greater energy used. Hence deeper breathing during time of exercise is a prime necessity in order to increase the absorbing surface of the lungs.

**Suffocation and Artificial Respiration.** — Suffocation results from the shutting off of the supply of oxygen from the lungs. It may be brought about by an obstruction in the windpipe, by a

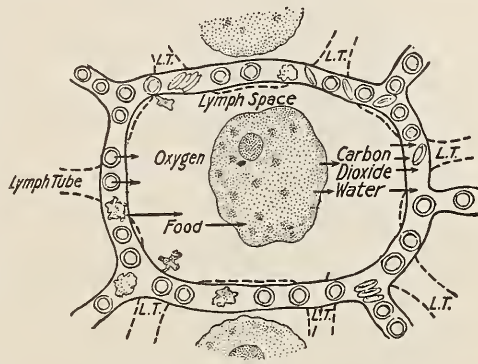
lack of oxygen in the air, by inhaling some other gas in quantity, or by drowning. A severe electric shock may paralyze the nervous centers which control respiration, thus causing a kind of suffocation. In the above cases, death often may be prevented by prompt recourse to artificial respiration. To accomplish this, lay the person face down, with the forehead resting on one arm. This position will bring the tongue forward and allow the water to escape from the lungs if it is a case of drowning. Now get astride of the patient, with one hand on each side of the body, place the fingers on the ribs and press down and in. Relax the pressure so as to allow air to get into the lungs. Repeat this about fifteen times a minute and continue if necessary for three or four hours.

Schaefer method of artificial respiration.

**Common Diseases of the Nose and Throat.** — Catarrh is a disease to which people with sensitive mucous membrane of the nose and throat are subject. It is indicated by the constant secretion of mucus from this membrane. Frequent spraying of the nose and throat with some mild antiseptic solution is found useful. Chronic catarrh should be attended to by a physician. Often we find children breathing entirely through the mouth because the air passages in the nose are closed. When this goes on for some time the nose and throat should be examined by a physician for *enlarged tonsils* and *adenoids*, or growths of soft masses of tissue which fill up the nose cavity, thus causing mouth breathing. Many a child, backward at school, thin and irritable, has been changed to a healthy, normal, bright pupil by the removal of adenoids. Sometimes the tonsils at the back of the mouth cavity become diseased as well as enlarged, and are the cause of colds and throat

troubles as well as the beginning of tuberculosis. Infected tonsils sometimes cause acute rheumatism and heart trouble.

**Cell Respiration.** — It has been found, in the case of very simple animals, such as the amœba, that when oxidation takes place in a cell, work results from this oxidation. The oxygen taken into the lungs is not used there, but is carried by the blood to such parts of the body as need oxygen to oxidize food materials in the cells. The quantity of oxygen used by the body is nearly dependent on the amount of work performed. From twenty to twenty-five ounces of oxygen is taken in and used by the body every day. Oxygen is constantly taken from the blood by tissues in a state of rest and is used up when the body is at work.



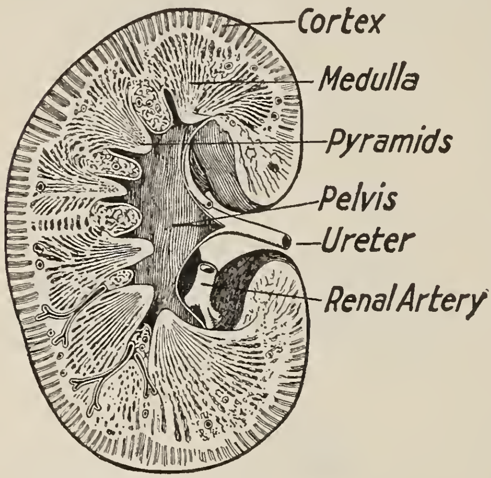
The respiration of a cell.

While work is being done certain wastes are formed in the cell. Carbon dioxide is released when carbon is burned; and when proteins are burned, a waste product containing nitrogen is formed. These wastes must be passed off from the cells, as they are poisons. Here again the blood and lymph, common carriers, take the waste materials to places where they may be *excreted* or passed out of the body.

**Organs of Excretion.** — All the life processes which take place in a living thing result ultimately, in addition to giving off carbon dioxide, in the formation of organic wastes which contain nitrogen. In animals one of these wastes is called *u'rea*. In man, the lungs, skin, and kidneys perform the function of eliminating wastes and are called the organs of excretion.

**The Human Kidney.** — The human kidney is about four inches long, two and one half inches wide, and one inch thick. Its color is dark red. If the structure of the medulla and cortex of the kidney (Figure, p. 384) is examined under the compound microscope, you will find these regions to be composed of a vast number of tiny branched and twisted tubules. The outer end of each of these tubules opens into the *pelvis*, the space within the

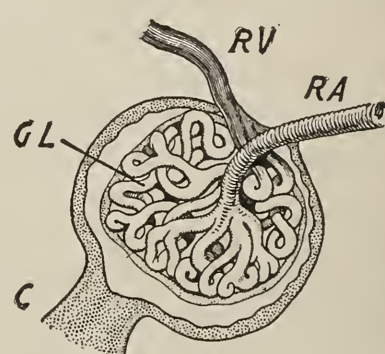
kidney; the inner end forms a tiny closed sac in the cortex. In each sac, the outer wall of the tube has grown inward and carried with it a very tiny artery which breaks up into a mass of capillaries. These capillaries, in turn, unite to form a small vein as they leave the little sac. Each of these sacs with its wall netted with blood vessels is called a *glomer'ulus.*




Lengthwise section of kidney.

**Wastes given off by the Blood in the Kidney.** — In the glomerulus the blood loses by osmosis, through the very thin walls of the capillaries, first, a considerable amount of water (amounting to nearly three pints daily); second, a nitrogenous waste material known as urea; third, salts and other waste organic substances, uric acid among them.

These waste products, together with the water containing them, are known as *urine.* The total amount of nitrogenous waste leaving the body each day is about twenty grams; this is nearly all accounted for in the urea passed off by the kidney. The urine is passed through the *ureter* (ū-rē'ter) to the *urinary bladder;* from this reservoir it is passed out of the body, through a tube called the *ure'thra.* After the blood has gone through the glomeruli of the kidneys it is purer than in any other place in the body, because, before going there, it lost a large part of its carbon dioxide in the lungs, and in the kidneys it lost much of its nitrogenous waste. So dependent is the body upon the excretion of its poisonous material that, in cases where the kidneys do not do their work properly, death may ensue within a few hours.




A glomerulus, much magnified: *RA*, small renal artery; *GL*, capillaries in the glomerulus; *RV*, small renal vein; *C*, tubule leading to the pelvis of the kidney.

**Structure and Use of Sweat Glands.** — If you examine the surface of your skin with a lens, you will notice the surface is

thrown into little ridges (see diagram, page 313). Between the ridges may be found a large number of very tiny pits; these are the pores or openings of the sweat-secreting glands. From each opening a little tube penetrates deep within the dermis; there, coiling around upon itself several times, it forms the sweat gland. Close around this coiled tube are found many capillaries. From the blood in these capillaries, cells lining the wall of the gland take water, and with it a little carbon dioxide, urea, and some salts (common salt among others). This forms the excretion known as *sweat*. The combined secretions from these glands amount normally to a little over a pint during twenty-four hours. At all times, a small amount of sweat is given off, which is evaporated or is absorbed by the underwear; as this passes off unnoticed it is called *insensible perspiration*. In hot weather or after hard manual labor the amount of perspiration is greatly increased.

**Relation of Body Heat to Work Performed.** — The body temperature of a person engaged in manual labor will be found to be but little higher than the temperature of the same person at rest. When a man works, he releases energy by oxidizing food material or tissue in the body and heat is released. Muscles, nearly one half the weight of the body, release about five sixths of their energy as heat. At all times they are giving up some heat. How is it that the body temperature is not much higher when work is being done than when at rest?

**Regulation of Heat of the Body.** — The temperature of the body is largely regulated by means of the activity of the sweat glands. The blood carries much of the heat, liberated in the various parts of the body by the oxidation of food, to the surface of the body, where it is lost in the evaporation of sweat. In hot weather the blood vessels of the skin are dilated; in cold weather they are made smaller by the action of the nervous system. The blood loses water in the skin, and as the water evaporates, we are cooled off. *The object of increased perspiration, then, is to remove heat from the body.* With a large amount of blood present in the skin, perspiration is increased; with a small amount, it is diminished. Hence, we have in the skin a regulator of body temperature under automatic control.

**Sweat Glands under Nervous Control.** — The sweat glands, like the other glands of the body, are under the control of the sympathetic nervous system. Frequently the nerves dilate the blood vessels of the skin, thus helping the sweat glands to secrete, by giving them more blood.

"Thus regulation is carried out by the nervous system determining, on the one hand, the loss by governing the supply of blood to the skin and the action of the sweat glands; and on the other, the production by diminishing or increasing the oxidation of the tissues." — Foster and Shore, *Physiology.*

**Comparison with Cold-blooded Animals.** — We have seen that the body temperature of a frog remains nearly the same as that of the surrounding medium. Fishes, all amphibious animals, and reptiles are alike in this respect. This change in the body temperature is due to the absence of regulation by the nervous system. A sort of regulation is exerted, however, by outside forces, for the cold in winter causes the cold-blooded animals to become inactive. Warm weather, on the other hand, stimulates them to greater activity and to increased oxidation. This is naturally followed by an increase in body temperature.

**Problem.** *A final study of changes in the composition of blood in various parts of the body. (Laboratory Manual, Prob. LIV; Laboratory Problems, Prob. 219.)*

**Summary of Changes in Blood within the Body.** — We have already seen that red corpuscles in the lungs lose part of their load of carbon dioxide that they have taken from the tissues, replacing it with oxygen. This is accompanied by a change of color from a deep crimson (in blood which is poor in oxygen) to that of bright scarlet (in richly oxygenated blood). More changes take place in other parts of the body. In the walls of the food tube, especially in the small intestine, the blood receives its load of fluid food. In various parts of the body it receives enzymes and hormones. In the muscles and other working tissues the blood gives up food and oxygen, receiving carbon dioxide and organic waste in return. In the liver, the blood gives up its sugar, and the worn-out red corpuscles which break down are removed (as they are in the spleen) from the circulation. In glands, it gives up materials used by the gland cells in their manufacture of secretions. In the kidneys, it loses water and nitrogenous wastes (*urea*). In the skin, it also loses some waste materials, salts, and water.

**Hygiene of the Skin.** — The skin as an organ of excretion is

of importance. It is of even greater importance as a regulator of body temperature. The mouths of the sweat glands must not be allowed to become clogged with dirt. The skin of the entire body should, if possible, be bathed daily. For those who can stand it, a cold shower or sponge bath in the morning is best. Soap should be used daily on parts exposed to dirt. Exercise in the open air is important to all who desire a good complexion.

**Cuts and Burns.** — In case the skin is broken the entrance and growth of bacteria may be prevented by applying iodine or by washing the wound with weak antiseptic solutions, such as 3 per cent *carbolic acid*, 3 per cent *lysol* (lī'sōl), *peroxide of hydrogen* (full strength), or a $\frac{1}{10}$ per cent solution of *bichlo'ride of mercury*. These solutions should be applied immediately. In the case of a burn apply a mixture of equal parts of linseed oil and lime water, or if this is not at hand cover the injured part with a paste of baking soda and water. In the case of a bad burn or deep cut call a doctor at once.

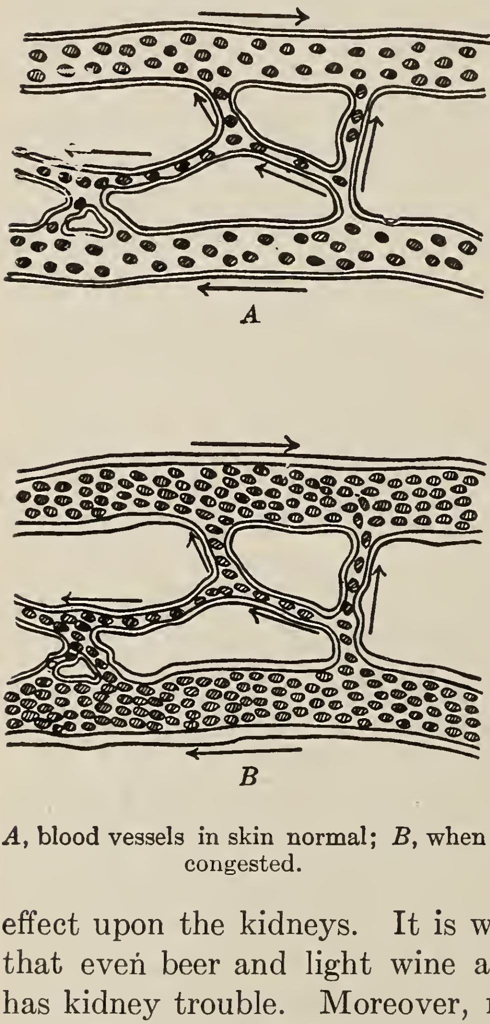
**Colds and Fevers.** — The regulation of blood passing through the blood vessels is under control of the nervous system. If this mechanism is interfered with in any way, the sweat glands may not do their work, perspiration may be stopped, and the heat from oxidation held within the body. The body temperature goes up, and a fever results.

If the blood vessels in the skin are suddenly cooled they contract and send the blood elsewhere. If the chilling of the blood is too great or lasts for too long a time, a congestion or cold follows. Colds are, in reality, a congestion of membranes lining certain parts of the body, as the nose, throat, windpipe, or lungs, and a growth of bacteria which were present in the mouth or throat. Some colds are contagious and gain entrance to the body when the resistance is low.

When suffering from a cold, it is therefore important not to chill the skin, as a full blood supply should be kept in it and away from the seat of congestion. For this reason hot baths (which call the blood to the skin), the avoiding of drafts (which chill the skin), and warm clothing are useful factors in the care of colds.

One of the greatest deceptions played upon the drinker by

alcohol is that it helps to make him warmer when he is cold. But this is far from the case. As a matter of fact he feels warmer for a little while because the alcohol paralyzes the nerves which control the amount of blood going to the skin and the skin becomes flushed and gorged with blood. But as we have seen under such conditions heat is lost from the blood through the skin. In a short time therefore the drinker has lost more heat than the abstainer and numerous cases are on record where drinkers have suffered or lost their lives from exposure while abstainers under the same conditions have survived.




*A*, blood vessels in skin normal; *B*, when congested.

Alcohol and tobacco have both been proved to have a bad effect upon respiration and the cells lining the respiratory organs. Statistics show without a doubt that the use of alcohol together with bad conditions of living has had a very serious effect in raising the death rate from tuberculosis of the lungs.

Alcohol also has a serious effect upon the kidneys. It is well known to alcoholic drinkers that even beer and light wine are prohibited to the man who has kidney trouble. Moreover, much of the fatty degeneration of the kidneys, and Bright's disease may be attributed directly to the overuse of alcohol.

**Summary.** — Respiration really takes place in the cells of the body where work is done. The structures which provide for this are the lungs and blood vessels, which allow the air taken in to come in contact with the blood through the delicate linings of the lung sacs.

Since oxidation takes place in cells the products of burning must be removed as well as other organic wastes. This is done eventually by the lungs, skin, and kidneys.

**Problem Questions.** — 1. How are the lungs adapted to their work?

2. Explain the mechanics of breathing.
3. What are the products of respiration?
4. What is ventilation? Why is it necessary?
5. What is cell respiration? Explain fully.
6. How does the kidney do its work?
7. How does the skin excrete wastes?
8. What is a congestion and how is it caused?

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# XXVIII. THE NERVOUS SYSTEM AND ORGANS OF SENSE

**Problem.** *A study of the nervous system, reactions to stimuli, and habit formation.* (*Laboratory Manual, Prob. LV; Laboratory Problems, Probs. 220 to 233.*)

**Divisions of the Nervous System.** — In a complicated machine like the human body there must be some means of obtaining coöperative action of the different organs toward definite ends. In the vertebrate animals, such as man, this is brought about by two divisions of the nervous system. One includes the brain, spinal cord, and cranial and spinal nerves, which together make up the *cerebro-spinal nervous system.* The other division is called the *autonom'ic* or *sympathetic nervous system.* The activities of the body are controlled from nerve centers by means of fibers which extend to all parts of the body, and end in muscles. The brain and spinal cord are examples of such centers, since they are largely made up of nerve cells. Small collections of nerve cells, called *ganglia,* are found in other parts of the body. These nerve centers are connected, to a greater or less degree, with the surface of the body by the nerves which serve as pathways between the end organs

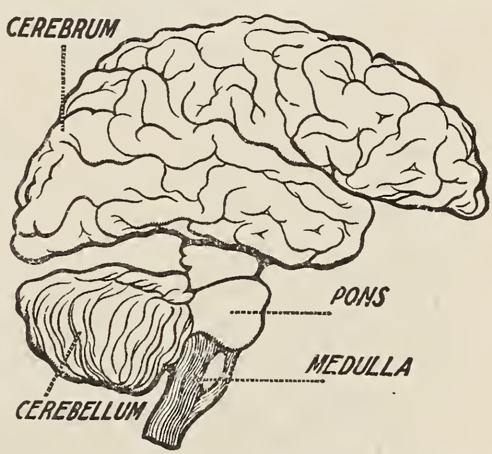
The central cerebro-spinal nervous system.


Diagram of a neuron or nerve unit.

of touch, sight, taste, etc., and the centers in the brain or spinal cord. Thus sensation is obtained.

**Nerve Cells and Fibers.** — A nerve cell, like other cells in the body, is a mass of protoplasm containing a nucleus, but, unlike them, it is usually rather irregular in shape, and possesses many delicate, branched protoplasmic projections. One of these, the *axis cylinder*, is much longer than the others and forms the pathway over which nervous impulses travel to and from the nerve centers. A nerve cell is a center of activity and sends impulses over this thin strand of protoplasm (the axis cylinder process) prolonged into a nerve fiber many hundreds of thousands of times the length of the cell. A nerve is a bundle of nerve fibers.

**The Brain of Man.** — In man, as in the frog, the central nervous system consists of a brain and spinal cord inclosed in a bony case with the nerves leaving it. From the brain, twelve pairs of nerves are given off; thirty-one pairs leave the spinal cord. The brain has three divisions. The *cerebrum* (sĕr′e-brum) makes up the largest part. In this respect it differs from the cerebrum of the frog and other vertebrates. It is divided into two lobes, the *hemispheres*, which are connected with each other by a broad band of nerve fibers. The outer layer of the cerebrum, which is thrown into folds or *convolutions*, is gray in color, and made up of nerve cells and supporting material. The inner part, which is white, is composed largely of fibers passing to other parts of the brain and down into the spinal cord. Under the cerebrum lies the little brain, or *cerebel′lum*. The two sides of the cerebellum are connected by a band of nerve fibers which run around into the lower hind-brain or *medul′la*. This band of fibers is called the *pons*.



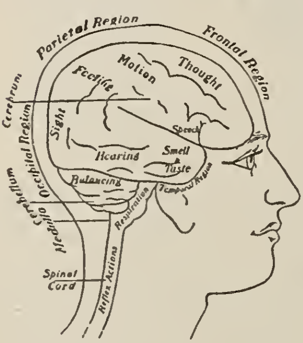
The brain, with parts separated to show each clearly.

**Sensory and Motor Nerve Fibers.** — Nerves which are connected with the central nervous system may be made up of fibers bearing messages from sense organs in the skin or elsewhere to the central nervous system, the *sensory* fibers, or of other fibers which carry impulses from the central nervous system to the outside, the *motor* fibers. Some nerves are made up of both kinds of fibers, in which case they are called mixed nerves.

**The Autonomic Nervous System.** — The autonomic (or sympathetic) nervous system consists of a series of ganglia connected with each other and with the central nervous system through some of the spinal and cranial nerves, especially the tenth cranial. The autonomic system, both in the frog and in man, controls the muscles of the digestive tract and blood vessels, the secretions of gland cells, and the heart.

**Functions of the Parts of the Central Nervous System of the Frog.** — From careful study of living frogs, birds, and some mammals we have learned much of what we know of the functions of the parts of the central nervous system in man.

It has been found that if the entire brain of a frog is destroyed or separated from the spinal cord, "the frog will continue to live but with a very peculiarly modified activity." It does not appear to breathe, nor does it swallow. It will not move or croak, but if acid is placed upon the skin so as to irritate it, the legs make movements to push away and to clean off the irritating substance. The spinal cord is thus shown to be a center for defensive movements. If the cerebrum is separated from the rest of the nervous system, the frog seems to act a little differently from the normal animal. It jumps when touched, and swims when placed in water. It will croak when stroked, or swallow if food be placed in its mouth. But it manifests neither hunger nor fear, and is in every sense a machine which will perform certain actions after certain stimulations. Its movements are automatic. If we watch the movements of a frog which has the brain uninjured in any way, we find that the frog acts spontaneously. It tries to escape when caught. It feels hungry and seeks food. It is capable of voluntary action. It acts like a normal individual.




Regions of the head and action of the different parts of the brain.

**Functions of the Cerebrum.** — In general, the functions of the different parts of the brain in man agree with those we have already observed in the frog. The cerebrum has to do with conscious activity. It presides over what we call our thoughts, our will, and our sensations. Each part of the area of the outer layer

of the cerebrum is given over to some one function, as speech, hearing, sight, touch, movements of body parts. The conscious movement of the smallest part of the body has its definite localized center in the cerebrum. Our knowledge on this subject is derived from experiments performed on monkeys, and from observations made on persons who had lost the power of movement of certain parts of the body, and were found, after death, to have had diseases localized in certain parts of the cerebrum.

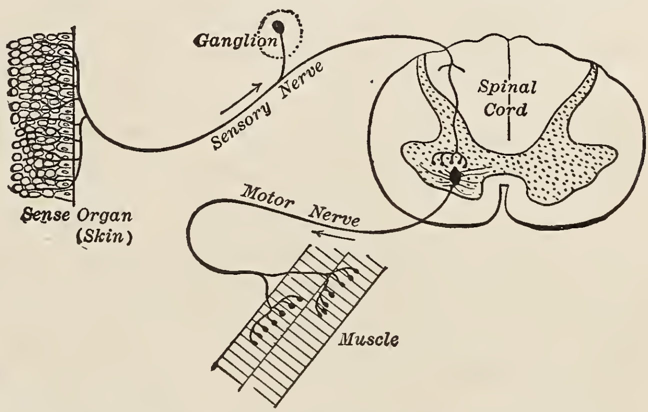


Diagram of the path of a simple nervous reflex action.

**Reflex Actions; their Meaning.** — If through disease or for other reasons the cerebrum does not function, no will power is exerted, nor are intelligent acts performed. All acts performed in such a state are known as *reflex actions*. An example of a reflex may be obtained by crossing the legs and hitting the knee a sharp blow. The leg, below the knee, will fly up as a result of reflex stimulation. The involuntary brushing of a fly from the face and the attempt to move away from the source of annoyance when tickled with a feather, are other examples. In a reflex act, a person does not think before acting. The nervous impulse comes from the outside to cells that are not in the cerebrum. The message is short-circuited back to the surface by motor nerves, without ever having reached the thinking centers. The nerve cells which take charge of such acts are located in the cerebellum or spinal cord.

**Automatic Acts.** — Some acts, however, are learned by conscious thought, as writing, walking, running, or swimming. Later in life, however, these activities become automatic and are controlled by the cerebellum, medulla, and spinal ganglia. Thus the thinking portion of the brain is relieved of part of its work.

**Habit Formation.** — The training of the different areas in the cerebrum to do their work efficiently is the object of education. When we learned to write, we exerted conscious effort in order to make the letters. Now the act of forming the letters is done without thought. By training, the act has become automatic. In the beginning, a process may take much thought and many trials before it is accomplished successfully. After a little practice, the same process becomes almost automatic and a habit is formed. Habits are really acquired reflex actions. They are the result of nature's method of training. The conscious part of the brain has trained the cerebellum or spinal cord to do certain things that, at first, were taken charge of by the cerebrum.

**Importance of forming Right Habits.** — Among the habits to be acquired early are the habits of studying properly, of concentrating the mind, of self-control, and above all, of contentment. Get the most out of the world about you. Remember that the immediate effect of the study of some subjects in school may not be great, but the cultivation of correct methods of thinking may be of the greatest importance later in life.

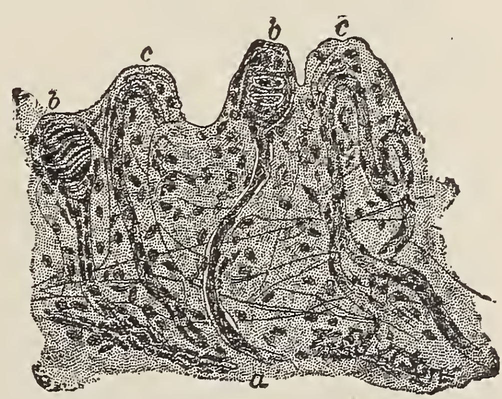
"The hell to be endured hereafter, of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters in the wrong way. Could the young but realize how soon they will become mere walking bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, 'I won't count this time!' Well! he may not count it, and a kind Heaven may not count it; but it is being counted none the less. Down among his nerve cells and fibers the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is, in strict scientific literalness, wiped out. Of course this has its good side as well as its bad one. As we become permanent drunkards by so many separate drinks, so we become saints in the moral, and authorities in the practical and scientific, spheres by so many separate acts and hours of work. Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he keep faithfully busy each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning, to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out." — James, *Psychology.*

**Necessity of Food, Fresh Air, and Rest.** — The nerve cells, like all other cells in the body, are continually wasting away and being rebuilt. Oxidation of food material is more rapid when we do mental work. The cells of the brain, like muscle cells, are not only capable of fatigue, but show this in changes of form and of contents. Food brought to them in the blood, plenty of fresh air, especially when engaged in active brain work, and rest at proper times, are essential in keeping the nervous system in condition. One of the best methods of resting the brain cells is a change of occupation. Tennis, golf, baseball, and other outdoor sports combine muscular exercise with brain activity of a different sort from that of business or school work, thus exercising other brain cells.

**Necessity of Sleep.** — Sleep is an essential factor in the health of the brain, especially for growing children. Most brain cells attain their growth early in life. Changes occur, however, until some time after the school age. Ten hours of sleep should be allowed for a child, and at least eight hours for an adult. It is during sleep that the brain cells have opportunity to rest and store food and energy for their working period.

## The Senses

**Touch.** — In animals having a hard outside covering, such as certain worms, insects, and crustaceans, minute hairs, which are sensitive to touch, are found growing out from the body covering. At the base of these hairs are found nerve cells which send nerve fibers inward to the central nervous system.




Nerves in the skin: *a*, nerve fiber; *b*, tactile papillæ, containing a tactile corpuscle; *c*, papillæ containing blood vessels. (After Benda.)

**Organs of Touch.** — In man, special nerve endings called the *tactile corpuscles*, which give the sense of touch, are located in the skin. The number of tactile corpuscles present

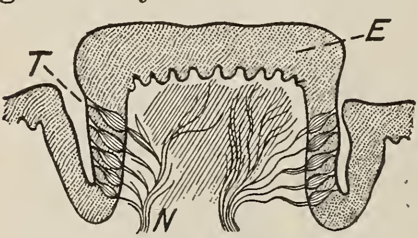
in a given area of the skin determines the accuracy and ease with which objects may be recognized by touch.

**Experiment: Touch.** — If you test the different parts of the body, as the back of the hand, the neck, the skin of the arm, of the back, or the tip of the tongue, with a pair of open dividers, a vast difference in the accuracy with which the two points may be distinguished is noticed. On the tip of the tongue, the two points need be separated by only $\frac{1}{24}$ of an inch to be distinguished. In the small of the back, a distance of two inches may be reached before the dividers feel like two points.

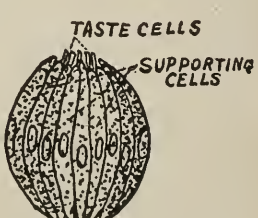
**Temperature, Pressure, Pain.** — The sensations of temperature, pressure, and pain are determined by different end organs in the skin. Two kinds of nerve endings exist in the skin, which give distinct sensations of heat and cold. These areas can be located by careful experimentation. There are also areas of nerve endings which are sensitive to pressure, and still others, most numerous of all, sensitive to pain.

**Taste Organs.** — The surface of the tongue is folded into a number of little projections known as papillæ. In the folds between these papillæ on the top and back part of the tongue, are located the organs of taste, called *taste buds*.

**How we Taste.** — Four kinds of substances may be distinguished by the sense of taste. These are sweet, sour, bitter, and salt. Certain taste cells located near the back of the tongue are stimulated only by a bitter taste. Sweet substances are perceived by cells near the tip of the tongue, sour substances along the sides, and salt about equally all over the surface. A substance must be dissolved in order to be tasted. Taste and smell are often confused and many things which we believe we taste are in reality perceived by the sense of smell. Such are spicy sauces and flavors of meats and vegetables. That we do not taste certain foods is proved easily by holding the nose and chewing several different substances, such as an apple, an onion, and a raw potato.



Section of circumvallate papilla: *E*, epidermis; *T*, taste buds; *N*, nerve fibers.

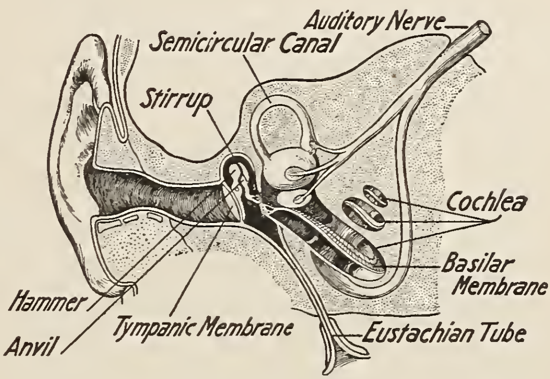


Isolated taste bud.

**Smell.** — The sense of smell is located in the membrane lining the upper part of the nose. Here are found a large number of rod-shaped cells which are connected with the forebrain by means of the olfactory

nerve. In order to perceive odors, it is necessary to have them diffused in the air; hence we sniff so as to draw in more air over the olfactory cells.

**Outer Ear.** — The organ of hearing is the ear. In the fish, frog, and reptile, the outer ear, so prominent in man, is entirely lacking. The outer ear consists of a funnel-like organ composed largely of cartilage which is of use in collecting sound waves; and the *auditory canal,* which is closed at the inner end by a tightly stretched membrane, the *tympan'ic membrane.* We have seen the tympanic membrane of the frog on the outer surface of the head. The function of the tympanic membrane is to receive sound waves, or vibrations in the air, which are transmitted, by means of a complicated apparatus found in the middle ear, to the inner ear.



Section of human ear.

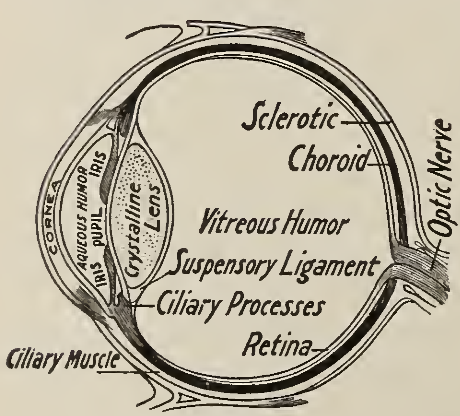
**Middle Ear.** — The middle ear in man is a cavity inclosed by the temporal bone of the skull and separated from the outer ear by the tympanic membrane. A little tube called the *Eustachian tube* connects the middle ear with the mouth cavity. By allowing air to enter from the mouth, the air pressure is equalized on the tympanic membrane. For this reason, we open the mouth at the time of a heavy concussion and thus prevent the rupture of the delicate tympanic membrane. Placed directly against the tympanic membrane and connecting it with another membrane which separates the middle from the inner ear, is a chain of three tiny bones, the smallest bones of the body. The outermost is called the *hammer;* the next the *incus,* or *anvil;* the third the *stirrup.* All three bones are so called from their resemblances in shape to the objects for which they are named. These bones are held in place by very small muscles which are delicately adjusted so as to tighten or relax the membranes guarding the middle and inner ear.

**The Inner Ear.** — The inner ear is one of the most complicated, as well as one of the most delicate, organs of the body. Deep within the temporal bone there are found two parts, one of which is called, collectively, the *semicircular canals*, the other the *cochlea* (kŏk′le-a), or organ of hearing.

It has been discovered by experimenting with fish, in which the semicircular canal region forms the chief part of the ear, that this region has to do with the equilibrium or balancing of the body. We gain knowledge of our position and our movements in space in part by means of the semicircular canals.

That part of the ear which receives sound waves is known as the *cochlea*, or snail shell, because of its shape. This very complicated organ is lined with sensory cells provided with cilia, and its cavity is filled with a fluid. It is believed that somewhat as a stone thrown into water causes ripples to emanate from the spot where it strikes, so sound waves are transmitted by means of the fluid filling the cavity to the sensory cells of the cochlea and thence to the brain by means of the auditory nerve.

**The Eye.** — The eye, or organ of vision, is an almost spherical body which fits into a socket of bone, the *orbit*. A stalklike structure, the *optic nerve*, connects the eye with the brain. Free movement is obtained by means of six little muscles which are attached to the outer coat of the *eyeball*, and to the bony socket around the eye.



Section of human eye.

The wall of the eyeball is made up of three coats. An outer tough white coat, of connective tissue, is called the *sclerot′ic coat;* this coat is lacking in the exposed part of the eyeball, but may be seen by lifting the eyelid. Where the eye bulges out a little in front, the outer coat is replaced by a transparent tough layer called the *cor′nea*. A second coat, the *choroid* (kō′roid), is supplied with blood vessels

and cells which contain pigments. The *i'ris* is the part of this coat which we see through the cornea as the colored part of the eye. In the center of the iris is a small circular hole, called the *pupil.* The iris is under the control of muscles, and may be adjusted to varying amounts of light, the hole becoming larger in dim light, and smaller in bright light. The inmost layer of the eye is called the *ret'ina.* This is, perhaps, the most delicate layer in the entire body. Despite the fact that the retina is less than $\frac{1}{80}$ of an inch in thickness, there are several layers of cells in its composition. The optic nerve enters the eye from behind and spreads out over the surface of the retina. Its finest fibers are ultimately connected with numerous elongated cells which are stimulated by light. The retina is dark purple in color, this color being due to a layer of cells next to the choroid coat and accounts for the black appearance of the pupil of the eye, when we look through it into the darkened space within the eyeball. The retina acts as the sensitized plate in the camera, for on it are received the impressions which are transformed and sent to the brain and result in sensations of sight. The eye, like the camera, has a lens. This lens is formed of transparent, elastic material. It is directly behind the iris, and is attached to the choroid coat by means of delicate ligaments. In front of the lens is a small cavity filled with a watery fluid, the *a'queous humor,* while behind it is the main cavity of the eye, filled with a transparent, almost jellylike, *vit'reous humor.* The elasticity of the lens permits a change of form and, in consequence, a change of focus upon the retina. By means of this change in form, or *accommodation,* we are able to see both near and distant objects clearly.

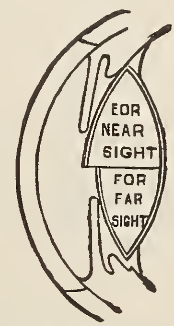



Diagram showing how the lens changes its form.

**Defects in the Eye.** — In some eyes, the lens is in focus for near objects, but is not easily focused upon distant objects; such an eye is said to be nearsighted. Other eyes which do not focus clearly on objects near at hand are said to be farsighted. Still another eye defect is *astig'matism,* which causes images of lines in a certain direction to be indistinct, while images of lines

transverse to the former are distinct. Many nervous troubles, especially headaches, may be due to eye strain.

**Experiment: How we See.** — Suppose an object be held in front of the eye; rays of light pass from every part of the object and are brought to a focus on the retina by means of the transparent lens. You can form an image in the same manner by using a reading glass, a box with a hole in one end, and a piece of white paper. Notice that the image is inverted. The same is true of the image on the retina. When an image is thrown

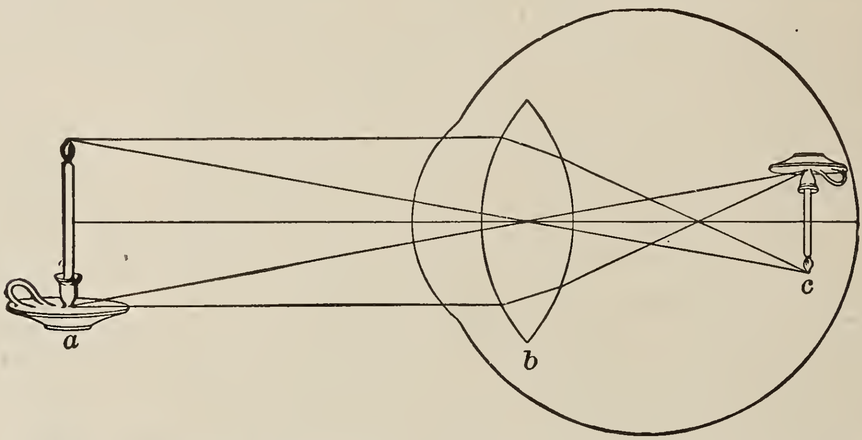



Diagram to show how an image is formed in the eye: *a*, object; *b*, lens; *c*, image upon retina.

on the sensory layer, the rods and cones of the retina are stimulated and the image is transmitted to the forebrain. We must remember that the optic nerve crosses under the brain so that images formed in the right eye are received by the left half of the forebrain, and *vice versa*.

**Care of the Eyes.** — Remember that a delicate organ like the eye is easily irritated and fatigued. Do not rub the eye, for it is easy to introduce germs by means of dirty fingers. If any foreign matter like dust gets in the eye, pull the upper lid down by means of the eyelashes. If the body is not removed by the flow of tears that follows, roll the upper eyelid back over a pencil or other small rounded object and remove the foreign body with a piece of clean, soft cloth. Boracic acid dissolved in warm water makes the best eye wash.

Fatigue of the eye may be brought about in a number of ways in which the tiny muscles of the eye are overtaxed and exhausted. Where a bright light falls on white paper and makes a reflection the eye becomes tired from trying to shut out some of the light.

Too much or too little light is bad, as is reading in a flickering light, as on the cars. Especially must we watch a farsighted eye for eye strain, as its vision seems perfect but there is a constant strain on the part of the muscles of accommodation which soon results in headache.

**Effects of Alcohol.** — We have already spoken of alcohol having a paralyzing effect upon the nervous system. This seems to be shown in a number of different ways.

Professor Hodge of Clark University describes many of his own experiments showing the effect of alcohol on animals. He trained four selected puppies to recover a ball thrown across a gymnasium. To two of the dogs he gave food mixed with dietetic doses of alcohol, while the others were fed normally. The ball was thrown 100 feet as rapidly as recovered. This was repeated 100 times each day for fourteen successive days. Out of 1400 times the dogs to which alcohol had been given brought back the ball only 478 times, while the others secured it 922 times. This seems to indicate that the puppies given alcohol in their diet did not react as quickly to the stimulus of the thrown ball as the others did. They were sluggish, both mentally and physically.

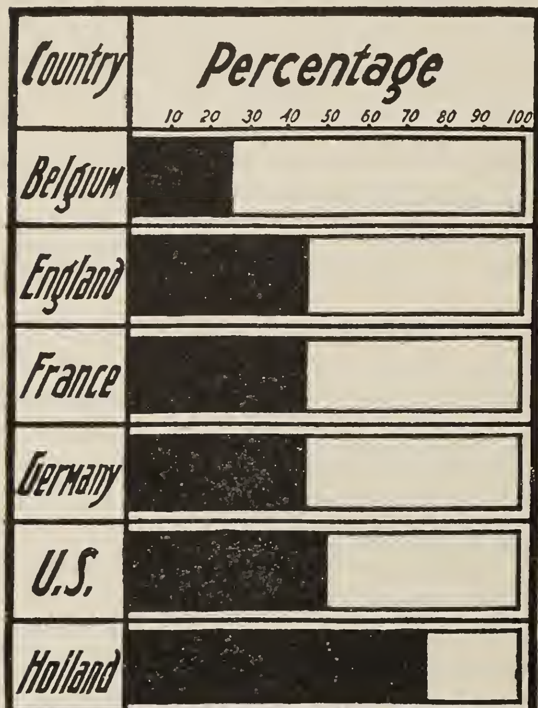
Dr. Parkes experimented with two gangs of men, selected to be as nearly similar as possible, in mowing. He found that with one gang abstaining from alcoholic drinks and the other not, the abstaining gang could accomplish more. On transposing the gangs the same results were repeatedly obtained. Similar results were obtained by Professor Aschaffenburg of Heidelberg University, who found experimentally that men "were able to do 15 per cent less work after taking alcohol."

**The Effect of Alcohol upon Intellectual Ability.** — It has been thought that alcohol in small quantities quickened the mental action, but a long series of experiments shows conclusively that this is untrue. Kraepelin shows that alcohol lengthens the time taken to perform complex mental work.

**The Drink Habit.** — One of the harmful effects of alcohol upon those who use it is the formation of the alcoholic habit. The first effect of drinking alcoholic liquors is that of exhilaration. After this feeling is gone, for it is a temporary state, the subject feels depressed and less able to work than before he took the drink. To overcome this feeling, he takes another drink. The result is that before long he finds a habit formed from which he cannot escape. With body and mind weakened, he attempts to break off the habit. But meanwhile his will, too, has suffered from overindulgence. He has become a victim of the drink habit!

Self-indulgence, whether in gratification of such a simple desire as for candy or the more harmful indulgence in tobacco or alcoholic beverages, is dangerous — not only in its immediate effects on the tissues and organs, but in its more far-reaching effects on habit formation.

**The Moral, Social, and Economic Effect of Alcoholic Poisoning.** — In the struggle for existence, it is evident that the man whose intellect is the quickest and keenest, whose judgment is most sound, is the one who is most likely to succeed. The paralyzing effect of alcohol upon the nerve centers must place the drinker at a disadvantage. In a hundred ways, the drinker sooner or later feels the handicap that the habit of drink has imposed upon him. Who knows the number of railway accidents that have been due to the uncertain eye of some engineer who mistook his signal?



Proportion of crime due to alcohol in various countries.

In business and in the professions, the story is the same. The abstainer wins over the drinking man.

*Not alone in activities of life, but in the length of life, has the abstainer the advantage.* Figures presented by life insurance companies show that the nondrinkers have a considerably greater chance of long life than do drinking men. So decided are the results shown by these figures that several companies have lower premiums for nondrinkers than for the drinkers who insure with them.

It is the economic argument that largely won the fight for prohibition that resulted in the Eighteenth Amendment. Thinking people all over the United States began to realize the

harm that the abuse of liquor wrought on the nation. Following the enforcement of the prohibition law, we find example after example of better economic conditions. Money which formerly went for drink is now used for better food and more of it, for useful and helpful articles in the home, for the purchase of homes and for investment and saving.

**Summary.** — It would be impossible to sum up in a few words the contents of this chapter. We have seen that the nervous system through its sense organs (as the eye, ear, and organs of pressure, touch, heat, cold, and taste) informs us concerning our environment. The central nervous system directs and coördinates action through the sensory and motor nerves and the brain. There is also an autonomic system which takes care of the body functions not under our control.

**Problem Questions.** — 1. What is the work of the central nervous system? of the autonomic nervous system? How have these facts been proved?

2. What are the functions of the cerebrum? the cerebellum? the spinal cord?

3. What is a neuron?

4. What is a reflex? Explain fully.

5. How are habits formed?

6. What are sensations? What are sense organs?

7. How do we taste? hear? see?

8. What are some eye defects and how may they be corrected?

9. What are the chief reasons against the use of alcohol from the standpoint of the nervous system?

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## XXIX. GOOD HEALTH AND HOW TO KEEP IT

**Problem.** *A study of personal hygiene. (Laboratory Manual. Prob. LVI; Laboratory Problems, Probs. 234 to 249.)*

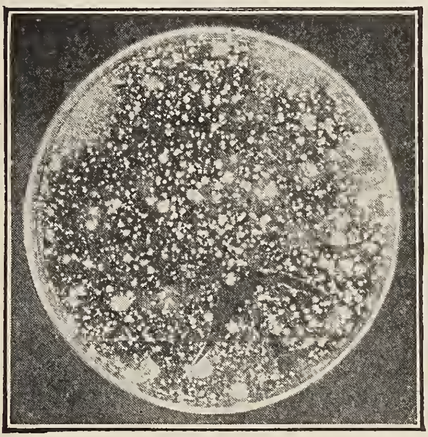
**Health and Disease.** — In previous chapters we have considered the body as a machine more delicate in its organization than the best-built mechanism made by man. In a state of health this human machine is in good condition; disease is a condition in which some part of the body is out of order, thus interfering with the smooth running of the mechanism.

**Personal Hygiene.** — It is the purpose of the study of hygiene to show us how to live so as to keep the body in a healthy state. Hygiene not only prescribes certain laws for the care of the various parts of the body, — the skin, the teeth, the food tube and the sense organs, — but it also shows us how to avoid disease. The foundation of health later in life is laid down at the time we are in school; for that reason, if for no other, a knowledge of the laws of hygienic living is necessary for all school children. Unlike some of the lower animals, we can change or modify our immediate surroundings so as to make them better and more hygienic places to live in. Hygienic conditions in homes and around them should be improved as we learn more about the value of a sanitary environment. It is the purpose of this chapter to show how we may do our share to coöperate with those in charge of the public health in our towns and cities.

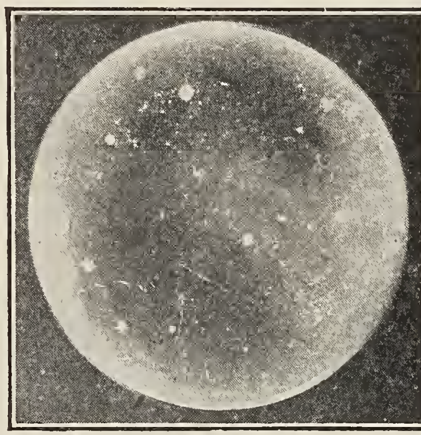
**Some Methods of Prevention of Disease.** — The proverb, "An ounce of prevention is worth a pound of cure," has much truth in it. Disease is largely preventable. Fresh air, the needed amount of sleep, moderate exercise, and pure food and water are *essentials* in hygienic living and in escape from disease.

**Pure Air Needed.** — What do we mean by fresh air, and why do we need it? We have already seen that oxidation takes

place within the body, and that air receives the carbon dioxide which is given off as a product of respiration. In addition to the carbon dioxide, water vapor and heat are given off as well as a very small amount of organic material of a poisonous nature. It is the presence of this material that gives rise to the odor noticeable in a close room. But other organic material is found in air. Dust from the street contains bacteria of many kinds, some of which may be disease-producing. Thus may be spread bacteria from the respiratory tracts of people who have



*A.*



*B.*

Two cultures. *A* was exposed to the air of a dirty street in the crowded part of Manhattan. *B* was exposed to the air of a well-cleaned and watered street in the uptown residence portion. Which culture has the more colonies of bacteria? How do you account for this?

colds, pneumonia, diphtheria, or tuberculosis. Much of the dust is dried excreta of animals. Soft-coal smoke does its share to add to the impurities of the air, while sewer gas and illuminating gas are frequently found in sufficient quantities to poison people. Pure air is, as can be seen, almost an impossibility in a great city.

**How to get Fresh Air.** — As we know, green plants give off in the sunlight considerably more oxygen than they use, and they take in carbon dioxide. The air in the country is naturally purer than in the city, as smoke and bacteria are not so prevalent there, and the numerous plants give off oxygen. In the city the night air is purer than day air, because the factories have stopped work, the dust has settled, and fewer

people are on the streets. The old myth that "night air" is injurious has long since been given up, and thousands of people of delicate health, especially those who have weak throats or lungs, are regaining health by sleeping out of doors or with the windows wide open. It is essential in sleeping out of doors or in a room with a low temperature that the body be kept warm and the head be protected from strong drafts by a night-cap or hood. Proper ventilation at *all* times is one of the greatest factors in good health.

**Change of Air.** — Persons in poor health, especially those having tuberculosis, are often cured by a change of air. This is not always due so much to the composition of the air as to change of occupation, rest, and good food. Mountain air is dry, and relatively free from dust and bacteria, and often helps a person having tuberculosis. Air at the seaside is beneficial for some forms of disease, especially hay fever and bone tuberculosis. Many sanitariums have been established for this latter disease near the ocean, and thousands of lives are being saved in this way.

Tracks of germs left by a fly crawling on sterilized media in a dish.

**The Relation of Pure Food and Pure Water to Health.** — Thanks to the care of state and city governments there is little need nowadays for the health of any individual to suffer from impure food or water. But that people do become sick and die from such causes every day is well known, as is shown by the many cases of typhoid fever, summer complaint, and ptomaine poisoning of various sorts. Our milk may have been watered or sent in cans washed with water containing typhoid germs, we may eat oysters bred in contaminated localities, we may have received and eaten fruits or vegetables sprinkled with water containing the germs. Our laws, however

good, cannot cope with human carelessness. Not only should we as individuals demand from the source of supply pure food and water, but we should do our share at home to keep them pure. Flies and other insects should be prevented from reaching food. Vegetables and fruits must not be eaten in an unripe or half-rotten condition, nor should the latter be canned or preserved. All raw fruits and vegetables should be either peeled or washed before eating. In general, foods may be made safe to eat by cooking long enough to kill the germs. Milk to be rendered absolutely safe should be pasteurized (so called after Louis Pasteur, the originator of the process), that is, heated to 160° Fahrenheit for 20 minutes. Ptomaine poisoning is often caused by bacteria in canned material which were not killed in the cooking and which act upon the proteins causing them to form poisons or ptomaines. Such foods are dangerous, for cooking does not destroy the poison. Meats which have been hung so long as to have an odor, and cold storage meats that appear to be decayed, should be avoided.

**Relation of Proper Exercise and Sufficient Sleep to Health.** — We are all aware that exercise in moderation has a beneficial effect upon the human organism. The pale face, drooping shoulders, and narrow chest of the boy or girl who takes no regular exercise are too well known. Exercise, besides giving work to the muscles, increases the activity of the heart and lungs, causing deeper breathing; it liberates heat and carbon dioxide from the tissues where the work is taking place, thus increasing the respiration of the tissues themselves, and aids mechanically in the removal of wastes from tissues. It is well known that exercise, when taken some little time after eating, has a very beneficial effect upon digestion. Exercise and games, especially if a change of occupation, are of immense importance to the nervous system as a means of rest. The increasing number of playgrounds in this country is due to this acknowledged need of exercise for growing children.

Proper exercise should be moderate and varied. Walking in itself is a valuable means of exercising certain muscles, and so is bicycling, but neither is ideal as the *only* form to be used. Vary

your exercise so as to bring different muscles into play, take exercise that will allow free breathing out of doors if possible, and the natural fatigue which follows will lead to the rest and sleep that every normal body requires.

Sleep is one way in which all cells in the body and particularly those of the nervous system get their rest. The nervous system, by far the most delicate and hardest worked set of tissues in the body, needs rest more than do other tissues, for its work directing the body ends only with sleep or unconsciousness. The afternoon nap, snatched by the brain worker, gives him renewed energy for his evening's work. It is not hard application to a task that wearies the brain; it is *continuous* work without rest.

**Effect of Alcohol on the Ability to Resist Disease.** — Among certain classes of people the belief exists that alcohol in the form of wine, beer, brandy, or some other drink, or in patent medicines, malt tonics, and the like, is of great importance in building up the body so as to resist disease or in curing it after disease has attacked it. Nothing is farther from the truth. In experiments on over three hundred animals, including dogs, rabbits, guinea pigs, fowls, and pigeons, Laitenen of the University of Helsingfors and Professor Frankel of Halle found that alcohol without exception made these animals more susceptible to disease than were the controls.

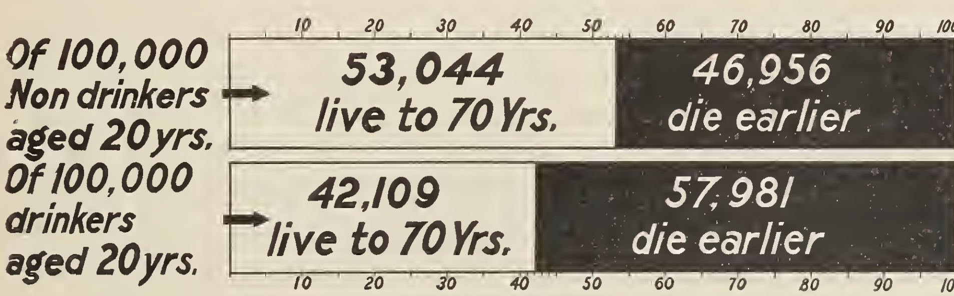
**Use of Alcohol in the Treatment of Disease.** — In the London Temperance Hospital alcohol was prescribed seventy-five times in thirty-three years. The death rate in this hospital has been lower than that of most general hospitals. One of the most serious misconceptions is that alcohol helps people who have tuberculosis to fight that disease successfully. Nothing is farther from the truth.

In a paper read at the International Congress of Tuberculosis, in New York, 1906, Dr. Crothers reported that alcohol as a remedy or a preventive medicine in the treatment of tuberculosis is a most dangerous drug, and that all preparations of sirups containing spirits increase, rather than diminish, the disease.

Professor Guttstadt of Berlin publishes statistics showing

that in Prussia of every 1000 deaths of men over twenty-five years, 161 are from tuberculosis. Of every 1000 deaths among bartenders, 556 are from tuberculosis; among brewery employees, 345; school-teachers, 143; physicians, 113; clergy, 76. The fifty-fifth annual report of the British Registrar General gives the average death rate of England as 13 per thousand, but among brewers it is 41 per thousand, only four occupations showing a higher rate.

**Experience of Insurance Companies.** — The United Kingdom Temperance and General Provident Institution of London insures in two departments, a general section and one for total abstainers. During the 60 years from 1841 to 1901 there were 31,776 whole-life policies in the general or nonabstaining section. These passed through 446,943 years of life, and there were 8947 deaths. In the abstaining section there were 29,094 whole-life policies, passing through 398,010 years of life, with 5124 deaths. If the death rate in the abstaining section had equaled that in the general section, there would have been 6959 deaths instead of 5124. In other words, the mortality averaged 36 per cent higher in the nonabstaining section than in the abstaining section.




Effect of drinking upon probability of long life.

In an article published in a book by Horsley and Sturge, Dr. Arthur Newsholme shows that of 100,000 total abstainers starting at the age of 20 years, 53,044 reach 70 years, while 46,956 die before 70 years; but of 100,000 moderate drinkers starting at 20, 42,109 reach 70 years, while 57,891 die before 70 years.

In the Scottish Temperance Life Assurance Society, in the

twenty years ending 1897, the deaths amounted to 69 per cent of the expected mortality in the general section, while in the total abstainers' section they amounted to only 47 per cent of the expected number. The number of deaths in the general section of the Sceptre of Life Association, England, was 80.34 per cent of the expectation in the fifteen years ending 1898, but in the total abstainers' section it was only 56.37 per cent of the expected mortality.

In considering the statistics of the insurance companies, it is well to remember that those insured in the general sections were picked men as well as those in the total abstainers' sections.

In discussing the experience of fraternal societies, Dr. Newsholme gives the following statistics from the report of the Public Actuary of South Australia: —

| | Average Mortality Per Cent | Average Sickness in Weeks |
|---|---|---|
| Abstainers' Societies | 0.689 | 1.248 |
| Nonabstainers' Societies | 1.381 | 2.317 |

| | Mortality Per Cent of Sick Members | Average Weeks of Sickness per Each Member Sick |
|---|---|---|
| Abstainers' Societies | 3.557 | 6.45 |
| Nonabstainers' Societies | 6.532 | 10.91 |

Attention should be called to the fact that the nonabstainers' societies have many members who are total abstainers, but, unlike the abstainers' societies, they do not refuse to admit nonabstainers. The number of weeks of sickness in the table refers to the average number of weeks for which the members call upon the sick fund of the society. All of these facts quoted prove that from the standpoint of health as well as economically alcohol is a menace.

**Rules of Hygiene.** — The following are rules of individual hygiene as summarized by Professor Irving Fisher, of Yale.

### Air

Keep out of doors as much as possible.

Breathe through the nose, not through the mouth.

When indoors, have the air as fresh as possible —

(*a*) By having aired the room before occupancy.

(*b*) By having it continuously ventilated while occupied.

Not only purity, but coolness, dryness, and motion of the air, if not very extreme, are advantageous. Air in heated houses in winter is usually too dry, and may be humidified with advantage.

Clothing should be sufficient to keep one warm. The minimum that will secure this result is the best. The more porous your clothes, the more the skin is educated to perform its functions with increasingly less need for protection. Take an air bath as often and as long as possible.

### Water

Take a daily water bath, not only for cleanliness, but for skin gymnastics. A cold bath is better for this purpose than a hot bath. A short hot followed by a short cold bath is still better. In fatigue, a very hot bath lasting only half a minute is good.

A neutral bath, beginning at 97° or 98°, dropping not more than 5°, and continued 15 minutes or more, is an excellent means of resting the nerves.

Be sure that the water you drink is free from dangerous germs and impurities. "Soft" water is better than "hard" water. Ice water should be avoided unless sipped and warmed in the mouth. Ice may contain *spores* of germs even when germs themselves are killed by cold.

Cool water drinking, including especially a glass half an hour before breakfast and on retiring, is a remedy for constipation.

### Food

Teeth should be brushed *thoroughly* several times a day, and floss silk used between the teeth. Persistence in keeping the mouth clean is good not only for the teeth, but for the stomach.

Masticate all food up to the point of involuntary swallowing, with the attention on the taste, not on the mastication. Food should simply be chewed and relished, with no thought of swallowing. There should be no more effort to prevent than to force swallowing. It will be found that if you attend only to the agreeable task of extracting the flavors of your food, nature will take care of the swallowing, and this will become, like breathing, involuntary. The more you rely on instinct, the more normal, stronger, and surer the instinct becomes. The instinct by which most people eat is perverted through the "hurry habit" and the use of abnormal foods. Thorough mastication takes time, and therefore one must not feel hurried at meals if the best results are to be secured.

Sip liquids, except water, and mix with saliva as though they were solids.

The stopping point for eating should be at the *earliest* moment when one is really satisfied.

The frequency of meals and time to take them should be so adjusted that no meal is taken before a previous meal is well out of the way, in

order that the stomach may have had time to rest and prepare new juices. Normal appetite is a good guide in this respect. One's best sleep is on an empty stomach. Food puts one to sleep by diverting blood from the head, but disturbs sleep later. Water, however, or even fruit may be taken before retiring without injury.

An exclusive diet is usually unsafe. Even foods which are not ideally the best are probably needed when no better are available, or when the appetite especially calls for them.

The following is a very tentative list of foods in the order of excellence for general purposes, subject, of course, to their palatability at the time eaten: fruits, nuts, grains (including bread), butter, buttermilk, salt in small quantities, cream, milk, potatoes, and other vegetables (if fiber is rejected), eggs, custards, digested cheeses (such as cottage cheese, cream cheese, pineapple cheese, Swiss cheese, Cheddar cheese, etc.), curds, whey, vegetables (if fiber is swallowed), sugar, chocolate, and cocoa, putrefactive cheeses (such as Limberger, Rochefort, etc.), fish, shellfish, game, poultry, meats, liver, sweetbreads, meat soups, beef tea, bouillon, meat extracts, tea and coffee, condiments (other than salt), and alcohol. None of these should be absolutely excluded, unless it be the last half dozen, which, with tobacco, are best dispensed with for reasons of health. Instead of excluding specific food, it is safer to follow appetite, merely giving the benefit of the doubt between two foods, equally palatable, to the one higher in the list. In general, hard and dry foods are preferable to soft and wet foods. Use some raw foods — nuts, fruits, salads, milk, or other — daily.

The amount of protein required is much less than ordinarily consumed. Through thorough mastication the amount of protein is automatically reduced to its proper level.

The sudden or artificial reduction in protein to the ideal standard is apt to produce temporarily a "sour stomach," unless fats be used abundantly.

*To balance* each meal is of the utmost importance. When one can trust the appetite, it is an almost infallible method of balancing, but some knowledge of foods will help. The aim, however, should always be — and this cannot be too often repeated — to educate the appetite to the point of deciding all these questions automatically.

## Exercise and Rest

The hygienic life should have a proper balance between rest and exercise of various kinds, physical and mental. Generally every muscle in the body should be exercised daily.

Muscular exercise should hold the attention, and call into play will power. Exercise should be enjoyed as play, not endured as work.

The most beneficial exercises are those which stimulate the action of the heart and lungs, such as rapid walking, running, hill climbing, and swimming.

The exercise of the abdominal muscles is the most important in order to give tone to those muscles and thus aid the portal circulation. For the same reason erect posture, not only in standing, but in sitting, is important. Support the hollow of the back by a cushion or otherwise.

Exercise should always be limited by fatigue, which brings with it fatigue poisons. This is nature's signal when to rest. If one's use of diet and air is proper, the fatigue point will be much farther off than otherwise.

One should learn to relax when not in activity. The habit produces rest, even between exertions very close together, and enables one to continue to repeat those exertions for a much longer time than otherwise. The habit of lying down when tired is a good one.

The same principles apply to mental rest. Avoid worry, anger, fear, excitement, hate, jealousy, grief, and all depressing or abnormal mental states. This is to be done not so much by repressing these feelings as by *dropping* or ignoring them — that is, by diverting and controlling the attention. The secret of mental hygiene lies in the direction of attention. One's mental attitude, from a hygienic standpoint, ought to be optimistic and serene, and this attitude should be striven for not only in order to produce health, but as an end in itself, for which, in fact, even health is properly sought. In addition, the individual should, of course, avoid infection, poisons, and other dangers.

Occasional physical examination by a *competent* medical examiner is advisable. In case of illness, competent medical treatment should be sought.

Finally, the duty of the individual does not end with personal hygiene. He should take part in the movements to secure better public hygiene in city, state, and nation. He has a selfish as well as an altruistic motive for doing this. His air, water, and food depend on health legislation and administration.

All the foregoing rules are important. The results which may be obtained by following them depend largely on the thoroughness with which they are followed. This is true especially of fresh air and mastication. If all the rules are followed and followed thoroughly, including the one most commonly neglected, — namely, keeping within the fatigue limit, — the average man may reasonably expect to add greatly to his length of life, his activity per day, his satisfactions, and his usefulness. The laws of "humaniculture" can be depended upon as much as those of agriculture, horticulture, or stock raising.

**Summary.** — The human machine, in order to do its most efficient work, must be properly cared for. This chapter has

given us some suggestions. Pure air and plenty of it, sunlight, pure food and water, a dietary selected from the best of foods given on page 412, rest and recreation as well as work and a careful following out of Dr. Fisher's laws of health will go far toward making each one of us healthy and happy.

**Problem Questions.** — 1. What has fresh air to do with health?

2. How can we get fresh air best in large cities?

3. What is pure water? How can we be sure it is pure?

4. What is pure milk and how can it be obtained?

5. What is the relation of exercise to health?

6. What is the relation of alcohol to health as proved by statistics?

7. Make up a balanced diet for yourself for one week. Why choose the foods you have taken?

8. What is fatigue? How does it cause trouble to a young person?

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# XXX. HEALTH AND DISEASE. A CHAPTER ON CIVIC BIOLOGY

***Problem.*** *How the civic authorities protect us from disease.*

**Public Sanitation and Hygiene.** — To-day, as never before, people are beginning to realize their part in the campaign against disease. Not only is the teaching of hygiene required in our schools but much practical health work is being done by the boys and girls in the schools. High school boys and girls have organized anti-fly and anti-mosquito campaigns which have resulted in the stamping out of diseases carried by flies and of malaria in some communities. High school boys and girls have organized sanitary and service squads which have resulted in better sanitary conditions in schools and school grounds. High school boys and girls have taken the inspiration for healthy living from their biology laboratories to their homes and have planted in them the seeds of practical hygiene and sanitation. This chapter may help other boys and girls to do their part in making conditions better in their communities.

**The Work of the Department of Street Cleaning.** — In any city one menace to the health of its citizens exists in the refuse and garbage. The city streets, when dirty, contain countless millions of germs which have come from decaying material, or from people ill with contagious diseases. In large cities a department of street cleaning not only cares for the removal of dust from the streets, but also has the removal of garbage, ashes, and other waste as a part of its work. The practice of putting *open* cans containing ashes and garbage into the street for removal is an indirect means of spreading disease, for flies breed and germs thrive in them. The street-cleaning department should be aided by every citizen; rules for the separation of garbage, papers, and ashes should be kept. Garbage and ash cans should be *covered.* The practice of upsetting ash or garbage

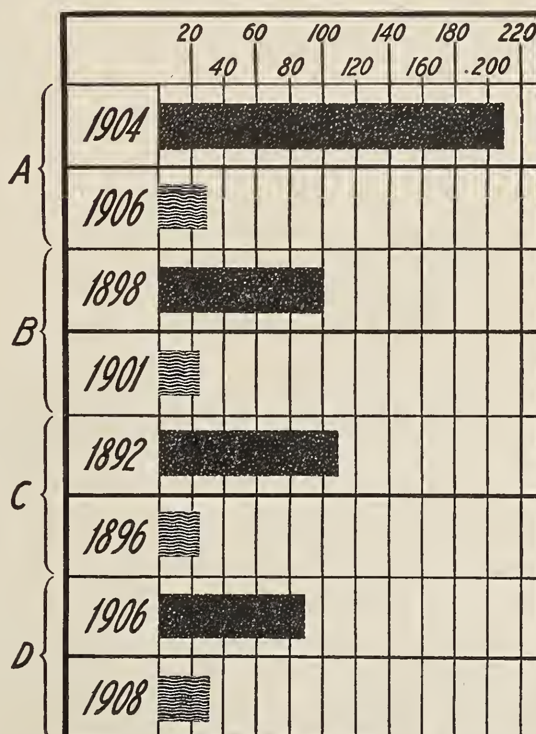
cans is one which no young citizen should allow in his neighborhood, for sanitary reasons. The best results in street-cleaning in summer are obtained by washing or flushing the streets, for thus the dirt containing germs is prevented from getting into the air. The garbage is removed in carts, and part of it is burned in huge furnaces. The animal and plant refuse is cooked in great tanks; from this material the fats are ex-

A style of truck for collecting rubbish (on top) and garbage or ashes (below).

tracted, and the solid matter is sold for fertilizer. Ashes are used for filling marsh land. Thus the removal of waste matter may pay for itself in a large city.

**The Necessity of a Pure Milk and Water Supply.** — The city of New York has spent hundreds of millions of dollars to bring a supply of pure water to her citizens. Other cities are doing the same. The world has awakened to the necessity of a pure water supply, largely because of the number of epidemics of typhoid which have been caused by contaminated water. Typhoid fever germs live in the food tube, hence the excreta of a typhoid patient contain large numbers of germs which often pass from the sewers into the drinking water. Many cities take

Growth of bacteria in a drop of impure water allowed to run down a steril ized culture in a dish.



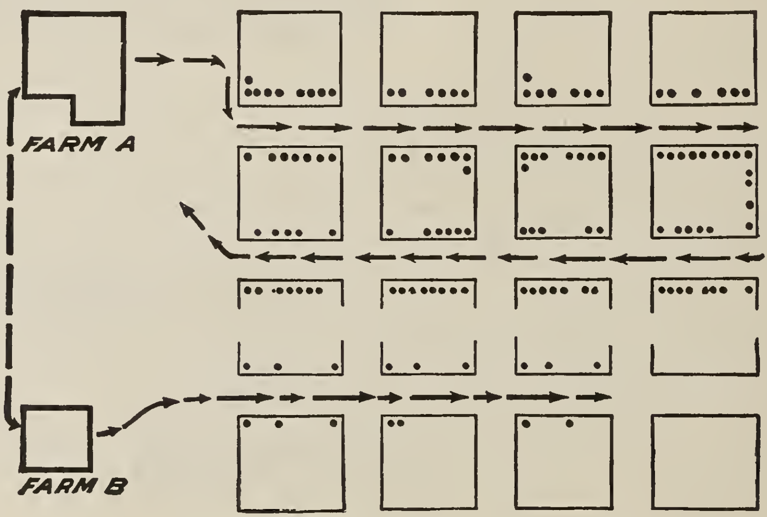

Cases of typhoid per 100,000 inhabitants before filtering water supply (solid) and after (shaded) in *A*, Watertown, N. Y.; *B*, Albany, N. Y.; *C*, Lawrence, Mass.; *D*, Cincinnati, O. What is the effect of filtering the water supply?

their water supply directly from rivers, sometimes not far below another large town. Such cities are in danger of having their water supply polluted. Some cities on very large lakes take their supply of water from the lakes into which their sewage flows. In cities which drain their sewage into rivers and lakes, the question of maintaining sanitary conditions is a large one, and many cities now have means of disposing of their sewage so that it is harmless to their neighbors. Filtering polluted water by passing it through settling basins and sand filters removes about 98 per cent of the germs. The results of drinking unfiltered and filtered water in certain large cities are shown graphically in the diagram. In addition to filtering, some cities add chlorine to their water in very minute quantities but enough to kill all harmful germs. Thus water from impure sources is made fit to drink.

In the country typhoid may be spread by the germs getting into a well or spring

from which the supply of water comes. This may be avoided by having privies and cesspools some distance from the well or spring and so placed that they drain *away* from it. Wells should have a cemented cap around the top so as to keep out surface water. The deeper water is less dangerous, as germs rarely live long more than five feet below ground.

Serious outbreaks of typhoid have been traced to contaminated milk supplies. A case of typhoid exists on a farm; the sewage gets into the well from which water is used for the washing of milk cans. Typhoid germs thrive in the milk. Thus




How typhoid may spread. Each square represents a city block, and each black dot represents a case of typhoid in houses supplied with milk from Farms *A* and *B*. There is a case of typhoid at Farm *A*. The cans from *B* are washed at *A* and returned to *B*.

the milkman spreads disease. The diagram on this page illustrates a recent epidemic, which was traced to a farm on which was a person having typhoid.

Railroads are often responsible for spreading typhoid. It is said that an outbreak of typhoid in Scranton, Pa., was due to the fact that the excreta from a typhoid patient traveling in a sleeping car were washed by rain into a reservoir near which the train was passing. Railroads are thus seen to be great open sewers. A sanitary car toilet should be provided so that filth and disease will not be scattered over the country.

**Work of a Board of Health.** — Although it is absolutely necessary for each individual to obey the laws of health if he or she wishes to keep from disease, it has also become necessary, especially in large cities, to have general supervision over the health of people living in a community. This is done by means of a department or board of health which cares for public health. A list of regulations and laws known as the *Sanitary Code* is given out to the citizens. These regulations concern the care of buildings and plumbing, the cleanliness of street cars and other public vehicles, the protection and supervision of foods sold, the inspection of our supplies of milk and water, and, particularly, the control of contagious diseases.

**How the Board of Health fights Typhoid and Other Diseases.** — Pure water is the first essential in preventing epidemics of typhoid. Health board officials are constantly testing the water supply, and if any harmful bacteria appear the water is chlorinated and a warning is sent out to *boil* the water. Boiling water for 10 minutes kills harmful germs.

The milk supply is also subject to rigid inspection. Milk brought into a city is tested, not only for the amount of cream present to prevent dilution with water, but also for the presence of germs. The cleanliness of the cans, wagons, etc., is also watched. The cows are also tested to see if they have tuberculosis, for infected cows *might* spread the disease to human beings.

During the summer months many babies die from diarrhœa. This disease is spread almost entirely through impure milk, which often becomes infected by flies carrying the germs to it. Spread of diseases through milk can be prevented by careful pasteurization (heating to 160° F. for 20 minutes). In many large cities pasteurized milk is sold at a reasonable price to poor people, and thus much disease is prevented.

**How the Board of Health fights Tuberculosis.** — Tuberculosis, which a few years ago killed fully one seventh of the people who died from disease in this country, now kills less than one tenth. This decrease has been largely brought about because of the treatment of the disease. Since it has been proved that tuberculosis if treated early enough is curable, by

quiet living, good food, and *plenty* of fresh air and light, we find that numerous sanatoria have come into existence which are supported by private or public means. At these sanatoria the patients *live* out of doors, and sleep in the open air, while they have plenty of nourishing food and little exercise. By tenement-house laws which require proper air shafts and window ventilation in dwellings, by laws against spitting in public places, and in many other ways, the boards of health in our towns and cities are waging war on tuberculosis.

Tuberculosis Camp, Raybrook Sanatorium, New York. Patients live in the open air the year round, with open tents for shelter.

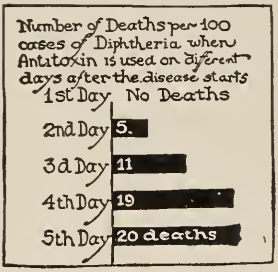
**Diseases Carried by Food.** — Disease germs of various sorts, typhoid, tuberculosis, scarlet fever, diphtheria, and many others may be transferred through the agency of food. Fruits and vegetables may be carriers of disease, especially if they are sold from exposed stalls or carts and handled by the passers-by. All vegetables, fruits, or raw foods should be carefully washed before using. Spoiled or overripe fruit, as well as meat which is decayed, is swarming with bacteria and should not be used. The board of health has supervision over the sale of fruit,

meats, fish, etc., and frequently in large cities food unfit for sale is condemned and destroyed.

**Infectious Diseases; Quarantine and Disinfection.** — One of the important means for preventing the spread of diseases caused by bacteria or protozoa is by *quarantine*, or isolation of the person who has the disease. No one save the doctor and nurse should enter the room of the person quarantined. After the disease has run its course, the clothing, bedding, etc., in the sickroom should be disinfected by boiling in soapy water. The patient should be washed carefully, including the mouth, face and hair, and should be dressed in sterile clothes before being allowed to see people again. The room should be thoroughly cleaned and the woodwork washed with hot soapy water. In this way disease germs are destroyed and the danger of contagion is prevented.

**Immunity.** — To prevent germ diseases we must kill many of the germs by attacking them directly with poisons (the poisons thus used are called *germicides* or *disinfectants*), and we must keep in such condition that we do not take disease when we come in contact with the germs that cause it. This insusceptibility or *immunity* may be either natural or acquired. Natural immunity seems to be in the constitution of a person, and may be inherited. It is racial, some races being more and others less susceptible to certain diseases. Natural immunity may be reduced by exposure to unfavorable conditions of temperature, by lack of proper food, by unsanitary living or working conditions and, in particular, by fatigue. This shows the importance of careful living on the part of each one of us. Immunity for some diseases may be acquired by means of *antitoxin*, as in diphtheria. This treatment, as the name denotes, is a method of neutralizing the poison (toxin) caused by the bacteria in the system. It was discovered by a German, Von Behring, that the serum of the blood of an animal immune to diphtheria is capable of neutralizing the poison produced by the diphtheria-causing bacteria in people. Horses develop large quantities of antitoxin when given the diphtheria toxin or poison. The serum (or liquid part) of the blood of these horses is then used to inoculate the patient suffering from or exposed to diphtheria, and thus the disease is checked or prevented

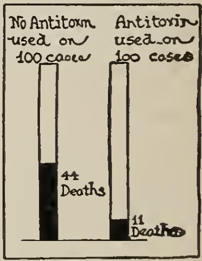
altogether. This is known as artificial immunity. By the *toxin-antitoxin* treatment, immunity to diphtheria can be given to those who have not been exposed to the disease. The *Schick test* determines at any time whether a child is already immune: a very small amount of diphtheria toxin is placed under the skin of the arm, and the spot will turn red if the child is not immune.




Antitoxin must be used in the early stages of diphtheria to be of value.

**Vaccination.** — Smallpox was once the most feared disease in this country; 95 per cent of the people suffered from it. As late as 1898, over 50,000 persons a year in Russia lost their lives from this disease. It is a contagious disease, probably not caused by bacteria, but by an animal germ. Smallpox has been brought under absolute control by vaccination with the substance (called *virus*) which causes cowpox in a cow. Cowpox is like a mild form of smallpox, and the introduction of this virus gives a person complete immunity to smallpox for several years after vaccination. This immunity is caused by the formation of a germicidal substance in the blood, due to the introduction of the vaccine containing the weakened virus. Vaccination was first tried by the English physician Jenner, who noted that dairymaids who had had cowpox did not take smallpox.

Vaccination for typhoid and paratyphoid is now practiced almost universally. Since the World War it has been proved that man can be kept free from these diseases, which in our Spanish-American War killed many times more soldiers than did Spanish bullets. This type of vaccination consists in introducing into the body the dead germs which cause typhoid. These germs have their toxins still in their dead bodies and immediately cause the blood to manufacture antibodies to fight the poisons thus introduced.




Typhoid antitoxin has greatly reduced the death rate from typhoid.

After three inoculations, each containing from 500,000,000 to 1,000,000,000 or more dead germs, the body obtains enough of the resistant antibodies to become immune

to typhoid. Similar treatment is also used for boils, colds, and influenza.

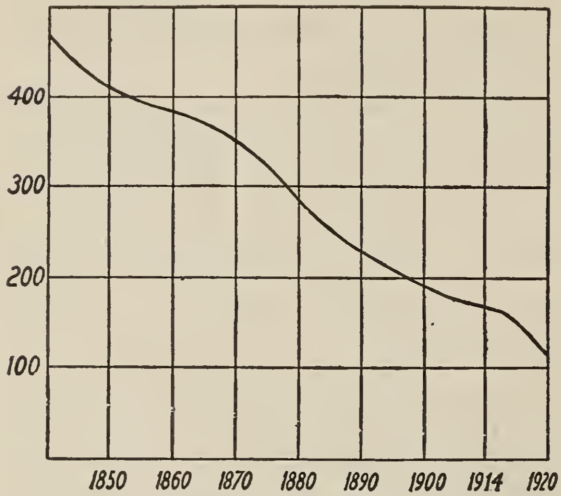
Immunity which is gained by the blood being stimulated to form antibodies which fight the bacteria or their poisons is known as *active immunity*. Examples of such immunity are seen in the treatment of smallpox or typhoid.

**Public Control of Disease.** — Not only do we have city health departments but state- and nation-wide agencies are at work also. State departments of health are active in twenty-six states. The Federal Public Health Service now exercises interstate control of communicable diseases — malaria, meningitis, hookworm, and the like. In addition to this the Rockefeller Institute is investigating the harm hookworm is doing all over the world. It has been found that 75 per cent of the inhabitants of Southern China, from 60 to 80 per cent of the 300,000,000 inhabitants of India, and practically all of the laborers of some South American tropical regions are infested with hookworms. Since this tiny organism not only reduces the working ability of a person, but also makes him much more liable to other diseases, especially tuberculosis, it can be seen that if the disease is stamped out the world will be much better off. This is not a difficult task if all coöperate, for the hookworms can be forced out of the body by means of thymol and Epsom salts.

Many other diseases, such as tuberculosis, bubonic plague, typhoid, and smallpox, will eventually be practically wiped out of existence by medical knowledge, and helpful coöperation of rich and poor alike.

**Summary.** — Examples of what private and public control of diseases may do are seen when we consider the specific case of the disease known as smallpox. In the eighteenth century 5,000,000 people are said to have died from it; one hundred years ago it was exceedingly common in all large cities in this country. To-day an epidemic of smallpox is impossible, thanks to the discovery of vaccination and prompt action by the health departments. Tuberculosis at the present time kills more people annually than any other disease, and yet it is believed that by sanitary living we shall stamp out the disease within fifty years if we go on at the present rate. Public

hygiene is largely responsible for the lessening of deaths from typhoid fever and other diseases which are transmitted through the milk and water supplies. It is estimated that pure milk, pure water, and pure air supplied to all would lengthen the average human life in the United States eight years. In this country and in parts of Europe where sanitation and hygiene are practiced, the life of human beings is gradually being lengthened. In India, on the other hand, where little hygiene is known or practiced among the masses of people, the length of life is not being increased. Theodore Roosevelt said in one of his last messages to Congress: —



The curve showing a decreasing death rate from tuberculosis. Why do fewer people die from the disease than formerly?

> "There are about 3,000,000 people seriously ill in the United States, of whom 500,000 are consumptives. *More than half of this illness is preventable.* If we count the value of each life lost at only $1700 and reckon the average earning lost by illness at $700 a year for grown men, we find that the economic gain from mitigation of preventable disease in the United States would exceed $1,500,000,000 a year. This gain can be had through medical investigation and practice, school and factory hygiene, restriction of labor by women and children, the education of the people in both public and private hygiene, and through improving the efficiency of our health service, municipal, state, and national."

**Problem Questions.** — 1. What is the value of public health agencies in a community?

2. How does water affect health? Milk? Foods?

3. How may typhoid be spread? tuberculosis?

4. What is immunity? How may it be obtained for typhoid? smallpox? diphtheria?

5. What public agencies control disease?

6. What is the hookworm disease and how may it be fought? (See pages 200–201.)

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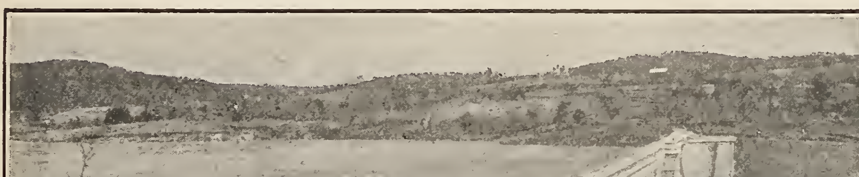

Part of the supply of pure water for the city of New York; the Croton Dam and Spillway.

# GLOSSARY OF SCIENTIFIC TERMS

(Generic and specific names are not included)

## A

**Abdo'men** (Lat. *abdomen*, belly): the third region of the body of an insect; the region of the body below the chest in man.

**Absorp'tion** (Lat. *absorbere*, to swallow down): the process of taking up food or other substances by chemical or molecular action from the digestive tract or elsewhere.

**Adapta'tion** (Lat. *adaptare*, to fit): fitness for surroundings; fitness to do a certain kind of work; changes which a plant or animal has undergone that fit it for the conditions in which it lives.

**Ad'enoids**: fleshy growths in the back of the nose cavity which clog the air passages.

**Adul'terant**: a substance put in another to cheapen it; usually reducing its strength or otherwise injuring it.

**Aëro'bic organisms**: bacteria or other organisms which require free oxygen as opposed to **anaërobic** organisms (bacteria and some parasitic worms) which do not require free oxygen.

**Al'cohol**: a narcotic poison.

**Al'ga** (pl. **Algæ**): a low form of plant containing chlorophyll. Its body is usually a thallus.

**Alterna'tion of generations**: the alternating of a sexual with an asexual phase in the life-history of a plant or animal.

**Anten'na** (pl. **Antennæ**) (Lat. *antenna*, a sailyard): a jointed feeler on the head of an insect or crustacean.

**Anten'nules**: small antennæ, or feelers.

**Ante'rior** (Lat. *anterior*, former): nearer the head end (Zoöl.); facing outward from the axis (Bot.).

**An'ther** (Gr. *antheros*, flowery): the part of the stamen which develops and contains pollen.

**An'tibodies**: substances found in the blood which fight against bacteria or prevent them from harming the body.

**Antisep'tic** (Gr. *anti*, against; *sepsis*, putrefaction): a substance which prevents the growth of harmful microörganisms.

**A'nus** (Lat.) the posterior opening of the food tube.

**Aor'ta** (Gr. *aorte*, from *aeirein*, to lift): the large artery leaving the left ventricle of the heart.

**Append'age**: a jointed organ attached to the side of the body.

**Ar′tery** (Lat. *arteria,* windpipe, artery): a tube which conveys blood from the heart.

**Asep′tic** (Gr. *a,* not; *septikos,* putrid): free from pus-forming bacteria or other harmful organisms.

**Asex′ual:** having no sex.

**Assimila′tion** (Lat. *assimilare,* to make like): the conversion of digested food into living matter.

**Astig′matism** (Gr. *a,* without; *stigma,* spot): a defect of the eye, caused by an irregularity in the curvature of the lens. It results in indistinctness of vision.

**Au′ricles** (Lat. *auricula,* little ear): chambers which receive blood when it enters the heart.

**Autonom′ic nervous system** (Gr. *autos,* self; *nomos,* province): a part of the nervous system not under control of the will; the sympathetic nervous system.

## B

**Bacil′lus:** a rod-shaped bacterium.

**Bacte′ria** (Gr. *bakterion,* a little staff): microscopic one-celled plants, some of which cause specific diseases.

**Bacteriology:** a study of bacteria.

**Bile:** a fluid secreted by the liver.

**Biol′ogy** (Gr. *bios,* life; *logos,* discourse): the study of matter in a living state, the study of plants and animals.

**Blade:** the flat portion of a leaf.

**Blas′tula** (Gr. *blastos,* a bud): a stage in the segmentation of an egg in which the cells form a hollow ball with a wall one layer thick.

**Bud:** an undeveloped branch.

## C

**Cal′orie (Large calorie)** (Lat. *calere,* to be warm): a heat unit, namely, the amount of heat required to raise the temperature of one kilogram of water one degree Centigrade.

**Calorim′eter:** a machine for measuring heat units.

**Cam′bium:** the growing layer of a stem.

**Cap′illaries** (Lat. *capillus,* a hair): minute tubes which connect arteries with veins.

**Capillar′ity:** a phenomenon shown by liquids rising in fine tubes.

**Car′apace** (Sp. *carapacho,* a covering): a shell-like covering on the dorsal side of some animals, as crustaceans.

**Carbohy′drate** (Lat. *carbo,* coal; Gr. *hydor,* water): a class of nutrients composed of carbon, oxygen, and hydrogen, having the oxygen and hydrogen in the same proportion as water.

**Car′bon** (Lat. *carbo,* coal): an element found in all organic compounds.

**Carbon dioxide:** a gas, a product of the oxidation of carbon.

**Cell:** the structural and physiological unit in plant and animal bodies. A small mass of protoplasm inclosed in a cell membrane and usually containing a nucleus.

**Cell membrane:** the delicate living covering of a cell.

**Cell sap:** water, with materials in solution, found in the vacuoles of plant cells.

**Cel'lulose:** a dead substance found in the cell walls of plants.

**Cen'trum** (Lat. *centrum,* center): the stout body of a vertebra.

**Cephalotho'rax** (Gr. *kephale,* head; *thorax,* chest): body region in crustaceans formed by the fusion of head and thorax.

**Cerebel'lum** (Lat., diminutive of *cerebrum*): part of the brain between the cerebrum and the medulla oblongata.

**Cer'ebrum** (Lat. *cerebrum,* the brain): the anterior part of the brain.

**Chel'ipeds** (Gr. *chele,* claw): pincher claws of arthropods.

**Chemical element:** a substance which has never been broken down into simpler substances.

**Chi'tin** (Gr. *chiton,* a tunic): a hard substance present in the exoskeleton of insects.

**Chlo'rophyll** (Gr. *chloros,* grass green; *phyllon,* a leaf): the green coloring matter of plants.

**Chlo'roplasts:** small bodies of protoplasm which contain chlorophyll.

**Cho'roid:** the middle coat of the eye.

**Chro'mosome** (Gr. *chroma,* color; *soma,* body): a deeply staining body in the nucleus of a cell, supposed to carry the determiners of hereditary qualities.

**Chrys'alis** (Gr. *chrysos,* gold): the uncovered pupal stage of butterflies.

**Cil'ium** (Lat. *cilium,* an eyelid with hairs growing on it): a tiny hairlike thread of protoplasm extending from a cell.

**Cloa'ca** (Lat. *cloaca,* sewer): the common cavity into which the digestive, urinary, and reproductive systems open in some kinds of vertebrates.

**Coc'cus** (Gr. *kokkus,* berry): a ball-shaped bacterium.

**Cocoon':** The egg-case of spiders; a silky covering around a pupa.

**Cœ'lom** (Gr. *koilos,* hollow): the true body cavity, through which the digestive tract passes.

**Compound eye:** an eye made up of many simple eyes or ommatidia. Arthropods have compound eyes.

**Conjuga'tion** (Lat. *cum,* together with; *jugare,* to yoke): the temporary union of two sex cells of equal size, with a fusion of nuclei and interchange of nuclear material.

**Connective tissue:** collections of cells which support and connect other tissues.

**Contrac'tile vac'uole:** a small vesicle, found in the cytoplasm of many protozoa, which appears and disappears with regularity. It is believed to be an organ of excretion.

**Cor'puscles** (Lat. *corpusculum,* a little body): the red and colorless cells in the blood.

**Cor'tex**: a fleshy portion of the root, outside the central cylinder.

**Cotyle'don** (Gr. *kotyledon*, socket): the seed leaves. Plants may be grouped as monocotyledons, having one seed leaf; dicotyledons, having two seed leaves; and polycotyledons, having many seed leaves.

**Cul'ture**: a growth of bacteria or other microörganisms in prepared nutrient media.

**Cy'toplasm** (Gr. *kytos*, a vessel; *plasma*, anything formed): the living substance of the cell outside of the nucleus and inside the cell membrane.

## D

**Dehis'cent fruits** (Lat. *de*, from; *hiscere*, to open): fruits that split open to discharge their seeds.

**Deliques'cent tree** (Lat. *deliquescere*, to melt, dissolve): a spreading tree, as the elm.

**Der'mis** (Gr. *derma*, skin): the layer of skin below the epidermis.

**Di'aphragm** (Gr. *diaphragma*, a partition wall): the muscular partition between the thorax and the abdomen.

**Di'astase**: an enzyme formed in plants which changes starch to grape sugar.

**Dichog'amy** (Gr. *dicha*, in two; *gamos*, marriage): a condition in which the stamens ripen before the pistil or vice versa, thus preventing self-pollination.

**Dicotyle'don**: a plant that bears seeds having two cotyledons.

**Diges'tion** (Lat. *digestio*, the dissolving of food): the process of preparing food for absorption.

**Dimor'phic** (Gr. *dis*, twice; *morphe*, form): flowers which have two forms, one having long pistils and short stamens, the other short pistils and long stamens.

**Disinfect'ant**: something which kills bacteria.

**Dor'sal** (Lat. *dorsum*, the back): of or pertaining to the back or top side.

**Ductless glands**: glands which have no communication with an outer surface, and which manufacture hormones.

## E

**Ec'toderm** (Gr. *ectos*, outside; *derma*, skin): the outer layer of a many-celled animal.

**Em'bryo** (Gr. *embryon*, a young one): the early stage of a developing plant or animal.

**Em'bryo sac**: the structure within the ovule which holds the egg cell.

**Emul'sion** (Lat. *emulgere*, to milk out): a mixture of liquids which do not dissolve, the particles of one floating as small globules in the other.

**En'doderm** (Gr. *endon*, within; *derma*, skin): the inner layer of cells in an embryo, giving rise to the digestive tract, etc.

**En'doskeleton** (Gr. *endon*, within; *skeletos*, hard): a skeleton inside the body as opposed to the outer or exoskeleton.

**En'dosperm** (Gr. *endon*, within): food stored in the seed outside the embryo.

**En'ergy** (Gr. *energos*, at work): work power; ability to perform work.

**Envi'ronment** (Fr. *environ*, about): the surroundings of an organism.

**En'zyme** (Gr. *en*, in; *zyme*, leaven): a substance which brings about a chemical action, assisting in digestion.

**Epider'mis** (Gr. *epi*, upon; *derma*, skin): an outer layer of cells; the outside skin.

**Ep'iphytes** (*epi*, upon; Gr. *phyton*, plant): air plants and tropical plants that obtain moisture from the atmosphere.

**Ero'sion** (Lat. *erodere*, to gnaw off): the wearing away of rocks through the agency of water, wind, glaciers, and other agencies.

**Essen'tial organs**: the stamens and pistils, parts of a flower which have to do with the production of seeds.

**Eusta'chian tube**: the canal connecting the tympanic cavity with the pharynx, named for its discoverer, *Eustachio*, an Italian physician.

**Excur'rent tree** (Lat. *ex*, out; *currere*, to run): a tall slender tree with one main trunk, as the cedar.

**Exoskel'eton**: an outside skeleton.

## F

**Fatigue'** (Lat. *fatigare*, to weary): the effect produced by long stimulation on the cells of an organism.

**Fats**: a class of nutrients composed of much carbon and hydrogen with a little oxygen.

**Fermenta'tion** (Lat. *fermentum*, ferment): the chemical transformation of organic substances through the agency of enzymes or ferments, or through the agency of bacteria.

**Fertiliza'tion** (Lat. *fertilis*, fruitful): the union of an egg cell and a sperm cell.

**Fibrovas'cular bundles**: collections of tubular cells, supported by woody cells, which conduct fluids in plants.

**Fin**: a fold of skin, with skeletal supports, used for swimming.

**Fis'sion** (Lat. *fissum*, cleft): division of a cell into two parts.

**Flagel'lum** (Lat. *flagellum*, whip): a vibratory threadlike projection of certain cells.

**Food**: a substance that forms the material for the growth or repair of the body of a plant or an animal or that furnishes energy for it.

**Fruit**: a ripened ovary together with any parts of the flower adhering to it.

**Func'tion** (Lat. *functio*, performance): the normal action of an organ or organs.

## G

**Game'tophyte** (Gr. *gamete*, wife): the phase in the life history of a thallus plant that produces the sex organs.

**Gan'glion (pl. Ganglia )** (Gr. *ganglion*, little tumor): a mass of nervous matter containing nerve cells which give rise to fibers.

**Gas'tric glands** (Gr. *gaster*, stomach): digestive glands found in the walls of the stomach.

**Gas'trula** (Gr. *gaster*, stomach): a cuplike structure formed by the invagination or turning in of the blastula.

**Geot'ropism** (Gr. *ge*, earth; *tropein*, to turn): response to gravity.

**Germina'tion**: the beginning of growth in a seed or pollen grain.

**Gill rakers**: small spinelike structures attached to gill arches which prevent escape of food.

**Gills**: breathing organs for use in water.

**Gland** (Lat. *glans*, an acorn): an organ which secretes material to be used in or excreted from the body.

**Gly'cogen** (Gr. *glykus*, sweet; *-gen*, producing): animal starch, found in the liver.

**Guard cells**: epidermal cells, found on each side of a stoma.

**Gul'let** (Lat. *gula*, gullet): a muscular canal extending from the mouth cavity to the stomach.

## H

**Hæmoglo'bin** (Gr. *haima*, blood; *globos*, sphere): red coloring matter of the blood.

**Hair follicle** (Lat. *folliculus*, a little bag): a little pit in the skin from which a hair grows.

**Hal'ophyte** (Gr. *hals*, salt): a plant which grows best in salty soils.

**Heliot'ropism** (Gr. *helios*, sun; *tropein*, to turn): response to light.

**Hered'ity** (Lat. *heres*, heir): transmission of qualities from parent to child.

**Hermaphrodit'ic** (Gr. *hermaphroditos*, combining both sexes): an organism having both male and female sex organs.

**Hi'lum**: a scar on the testa left where the seed was attached to the pod.

**Hor'mones** (Gr. *hormaein*, to excite): substances from the organs of the body which effect a chemical coördination.

**Hu'mus** (Lat. *humus*, ground): vegetable mold, a black or dark colored substance formed by the decay of organic substances in the soil.

**Hy'brid** (Lat. *hybrida*, mongrel): the offspring of parents of two different species or varieties.

**Hy'drophyte** (Gr. *hydor*, water): a water-loving plant.

**Hy'giene** (Gr. *hygeia*, health): a study of the preservation of health.

**Hypocot'yl** (Gr. *hypo*, under): the part of the developing embryo which forms the root and the lower part of the stem.

## I

**Immu'nity** (Lat. *immunis*, free from duty): the successful resistance of an organism to infections from microörganisms.

**Imperfect flowers**: flowers having only one kind of essential organs, either stamens or pistils.

**Intes'tine** (Lat. *intestinus*, internal): the food tube in vertebrates from the

pyloric end of the stomach to the anus. It is divided into the small and the large intestine.

**In'volucre** (Lat. *involucrum*, a wrapper): a whorl of leaflike bracts around the base of a flower cluster.

**I'ris** (Gr. *iris*, rainbow): the colored portion of the eye, having the pupil in the center.

## K

**Kid'neys:** glands which secrete urine.

**Kinet'ic** (Gr. *kinein*, to move): energy employed in producing motion.

## L

**Lac'teals** (Lat. *lacteus*, milky): lymphatic vessels which carry fats and other substances from the intestine to the thoracic duct.

**Lar'va** (Lat. *larva*, a ghost): an embryo which becomes self-sustaining but which does not have the characteristics of the adult.

**La'tent** (Lat. *latere*, to lie hid): lying dormant but capable of development.

**Leg'umes** (Lat. *legere*, to gather): plants which bear seeds in pods—peas, beans, and the like; also the seeds of such plants.

**Len'ticel:** a breathing hole in the bark.

**Lig'ament** (Lat. *ligare*, to bind): a band of connective tissue binding one bone to another.

**Liv'er:** a digestive gland which secretes bile.

**Lymph** (Lat. *lympha*, water): plasma and colorless corpuscles outside of the blood vessels.

## M

**Macronu'cleus** (Gr. *makros*, large): the large nucleus, as opposed to the **micronucleus,** or small nucleus.

**Mam'mary glands** (Lat. *mamma*, breast): milk-secreting glands found in mammals.

**Man'dible** (Lat. *mandere*, to chew): in insects, a hard cutting jaw.

**Man'tle** (Lat. *mantellum*, a cloak): the soft outer fold of skin in mollusks which secretes the outer shell.

**Maxil'la** (Lat. *maxilla*, a jaw): an appendage near the mouth of arthropods, modified in insects to form an organ for getting food.

**Maxil'liped** (Lat. *maxilla*, jaw; *pes*, foot): an appendage next posterior to the maxilla in arthropods. Foot jaw.

**Medul'la oblonga'ta** (Lat. *medulla*, pith): the most posterior part of the brain.

**Med'ullary rays** (Lat. *medulla*, pith): thin plates of pith which separate the wood of dicotyledonous stems into wedge-shaped masses.

**Mes'oderm** (Gr. *mesos*, middle; *derma*, skin): the middle layer of cells in a young animal embryo.

**Mes'ophyte** (Gr. *mesos*, middle): a plant preferring moderate conditions of moisture.

**Metamor'phosis** (Gr. *meta*, after; *morphe*, form): change of form undergone from egg to adult, as in insects.

**Metazo'a** (Gr. *meta*, after; *zoon*, animal): animals having many cells in the body.

**Mic'ropyle** (Gr. *micropyle*, a little gate): the hole where the pollen tube enters the embryo sac.

**Mid'rib**: central vein of a leaf.

**Mi'grant**: an animal which moves from one place to another and back regularly at stated seasons of the year. Many birds migrate to warmer regions for the winter.

**Mim'icry** (Gr. *mimikos*, imitative): the imitation in form or color of a harmful insect by a harmless one which is protected thereby.

**Monocotyle'don**: a plant that bears seeds having but one cotyledon.

**Mo'tor** (Lat. *movere*, to move): connected with movement.

**Mu'cous membrane** (Lat. *mucus*, slime; *membrana*, skin): a delicate moist membrane lining all body passages which have an external opening.

**Mus'cle** (Lat. *musculus*, muscle): a contractile tissue capable of bringing about movement.

**Muta'tion**: a heritable modification arising from internal causes in an organism.

**Myce'lium**: the threadlike body of a mold, the individual threads being called hyphæ.

## N

**Narcot'ic** (Gr. *narkotikos*, making dumb): a substance which blunts the senses and in large quantities causes insensibility.

**Nec'tar** (Gr. *nectar*, drink of the gods): a sweet fluid secreted by certain groups of cells known as nectar glands in a flower. From this substance bees make honey.

**Nic'titating membrane** (Lat. *nictare*, to wink): the third eyelid, a delicate membrane covering the eye in birds and frogs.

**Ni'trogen** (Lat. *nitrum*, natron; *-gen*, producing): a gaseous element, found in many organic compounds and forming almost four fifths of the atmosphere.

**Nu'cleus** (Lat. *nucleus*, a kernel): the center of activity in the cell.

## O

**Ommatid'ium** (Gr. *omma*, eye): one of the elements of a compound eye.

**Oper'culum** (Lat. *operculum*, a lid): a lid or flap in fishes, covering the gills.

**Op'sonin** (Gr. *opsonein*, to cater for): a substance in the blood which helps colorless corpuscles destroy bacteria.

**Or'ganism** (Gr. *organon*, an instrument): a body which is made up of organs or parts, each of which has a special function; any animal or plant.

**Osmo′sis:** diffusion of dissolved substances through a semi-permeable membrane, the greater flow being toward the denser medium.
**O′vary** (Lat. *ovum*, egg): the base of a pistil, containing the ovules.
**Ovipos′itor** (Lat. *ovum*, egg; *ponere*, to place): a specialized structure for depositing eggs, found in insects.
**Oxida′tion:** the chemical union of oxygen with some other substance.
**Ox′ygen** (Gr. *oxus*, acid; *-gen*, producing): a gaseous element found in the air and in many compounds.

## P

**Pal′ate** (Lat. *palatum*): the roof of the mouth. The hard palate is supported by bone; the soft palate is a fold of mucous membrane lying posterior to the hard palate.
**Pal′pus or palp** (Lat. *palpare*, to touch): in arthropods, an appendage attached to a mouth part; usually an organ of touch or taste.
**Pan′creas** (Gr. *pan*, all; *kreas*, flesh): a digestive gland which secretes pancreatic juice.
**Pap′pus:** a downy or fluffy outgrowth from the ovary wall.
**Par′asite:** an organism which secures its living directly from another living organism without giving anything in return.
**Pas′teurize** (from Pasteur the scientist, p. 3): to heat milk to about 160° Fahrenheit for about 20 minutes for the purpose of killing bacteria in it.
**Pec′toral girdle** (Lat. *pectoralis*, pertaining to the breast): bones which support the anterior pair of appendages in vertebrates.
**Pel′vic girdle** (Lat. *pelvis*, a basin): the bony arch to which the posterior pair of appendages are attached in vertebrates.
**Pet′al:** one of the leaflike parts of the corolla.
**Pet′iole** (Lat. *petiolus*, a little foot): the stalk of a leaf.
**Phag′ocyte** (Gr. *phagein*, to eat; *kytos*, cell): a colorless corpuscle which destroys bacteria.
**Phar′ynx** (Gr. *pharynx*, gullet): an irregular cavity at the back of the mouth.
**Phlo′ëm** (Gr. *phloos*, bark): the outer part of a fibrovascular bundle containing the sieve tubes.
**Photosyn′thesis** (Gr. *phos*, light; *synthesis*, a putting together): the process of making starch out of carbon dioxide and water by the aid of sunlight, as done by a green cell.
**Physiolog′ical division of labor:** performance of different kinds of work by different parts of an organism.
**Physiol′ogy** (Gr. *physis*, nature; *logos*, discourse): study of the functions of plants and animals.
**Pis′til:** a structure in the flower containing the ovary, in which the seeds are formed.
**Pith:** the soft, spongy center of a dicotyledonous stem.
**Plas′ma** (Gr. *plasma*, anything formed or molded): the colorless fluid part of blood.

**Pleu'ra** (Gr. *pleura*, the side): the membrane which covers the lungs and lines the cavity containing them.

**Plu'mule:** the part of the embryo above the cotyledons which develops into the stem and leaves.

**Pol'len grain:** a structure in flowers which contains the sperm cell or male gamete.

**Pollina'tion:** the transfer of pollen from the anther to the stigma. Self-pollination is transfer between parts in the same flower; cross-pollination is transfer between different flowers, or, some say, between flowers on different plants.

**Polycotyle'don:** a plant that bears seeds having several cotyledons.

**Pol'yp** (Lat. *polypus*, a polyp): a simple actinozoan, as a sea anemone or a single coral individual.

**Poste'rior** (Lat. *posterior*, later): behind, last, or tail end of an animal.

**Pri'mates:** the highest order of mammals, including the monkeys, the apes, and man.

**Probos'cis** (Gr. *pro*, before; *boskein*, to feed): a slender sucking tube found in insects.

**Proglot'tids** (Gr. *pro*, forward; *glotta*, tongue): reproductive body segments of a tapeworm.

**Pro'leg:** an unjointed abdominal appendage of insect larvæ.

**Prosto'mium:** a projecting part of upper lip of the earthworm.

**Protec'tive resemblance:** the likeness of living organisms in color or form to their immediate surroundings, thus securing protection from attack of enemies.

**Pro'teins** (Gr. *protos*, first): nitrogenous compounds found in the bodies of plants and animals; a class of nutrients composed of nitrogen, carbon, hydrogen, and oxygen, together with other elements in some cases.

**Pro'toplasm** (Gr. *protos*, first; Lat. *plasma*, a thing formed): the living substance of plants and animals.

**Protozo'a** (Gr. *protos*, first; *zoon*, animal): one-celled animals.

**Pseudopo'dium** (Gr. *pseudes*, false; *pous*, foot): a projection of protoplasm used for locomotion in protozoa.

**Pto'maine** (Gr. *ptoma*, a corpse): poisonous alkaloidal material probably the result of decomposition of organic matter.

**Pu'pa** (Lat. *pupa*, puppet): the quiescent stage in insect development preceding the adult.

**Pylo'rus** (Gr. *pyloros*, gatekeeper): the opening of the stomach into the intestine.

## Q

**Quar'antine** (Fr. *quarante*, forty): isolation of the sick to prevent spread of infectious disease.

## R

**Ray flowers:** modified flowers at the outer edge of a flower cluster such as a composite head.

**Regenera'tion** (Lat. *re*, again; *generare*, to beget): the growing again of a part of an animal which has been lost.

**Respira'tion** (Lat. *re*, again; *spirare*, to breathe): taking in of oxygen and giving out of carbon dioxide by living cells.

**Ret'ina** (Lat. *rete*, a net): the coat of the eye in which the optic nerve fibers terminate.

## S

**Sali'va** (Lat. *saliva*, spittle): the secretion of the salivary glands.

**Sap'rophyte** (Gr. *sapros*, rotten; *phyton*, plant): an organism which derives its nourishment from dead organic matter, as a mold or mushroom.

**Sclerot'ic coat** (Gr. *skleros*, hard): the outer coat of the eye.

**Scute** (Lat. *scutum*, a shield): an external scale, as in the snake.

**Seed**: a structure formed in a fruit as a result of the fertilization of the egg cell.

**Seg'ment** (Lat. *segmentum*, a piece cut off): one of a number of serial divisions of an animal's body or of an organ.

**Sen'sory** (Lat. *sensus*, feeling): having direct connection with any part of the seat of sensation.

**Se'pal**: a leaflike part of the calyx or outer circle of parts in a flower.

**Se'tæ** (Lat. *seta*, a bristle): bristles, used for locomotion in earthworms and other animals.

**Sex'ual** (Lat. *sexus*, sex): pertaining to or having sex.

**Si'phon** (Gr. *siphon*, a tube): a tube through which water may pass into and out from the mantle cavity of a mollusk.

**Spe'cies**: the smallest group of organisms having characteristics in common that make them different from all other organisms.

**Sperm cell**: the male sex cell or gamete.

**Spi'nal cord**: a cord of nervous tissue lying in the vertebral column.

**Spir'acles** (Lat. *spiraculum*, breathing hole): breathing holes in insects.

**Spiril'lum** (Lat. *spira*, coil): a spiral form of bacteria.

**Spongy paren'chyma** (Gr. *para*, beside; *en*, in; *chein*, to pour): a layer of loosely placed cells forming a tissue in the leaf.

**Sporan'gium** (Gr. *sporos*, a seed; *aggeion*, a vessel): a sac containing spores.

**Spore**: a reproductive cell capable of growing into a mature organism.

**Spo'rophyte**: spore-bearing part of a plant.

**Sta'men**: an organ of the flower in which pollen is formed.

**Ster'ilize** (Lat. *sterilis*, barren): to destroy bacteria and other organisms, usually by heating.

**Stig'ma** (Gr. *stigma*, the prick of a pointed instrument): the part of a pistil which receives the pollen grains.

**Stim'ulant** (Lat. *stimulus*, a goad): a substance which causes temporary activity of nerve or muscle.

**Stim'ulus** (Lat. *stimulare*, to incite): an agent which causes an organism or some part of it to react when affected by it.

**Stip'ule** (Lat. *stipula,* stem): a leaflike outgrowth at the base of the petiole.

**Sto'ma** (pl. **Sto'mata**) (Gr. *stoma*, a mouth): a breathing hole in a leaf.

**Stom'ach** (Gr. *stomachos*, throat): a sac-like part of the food tube between gullet and intestine.

**Sweat glands**: excretory glands in the skin.

**Swim'merets**: paired appendages on the abdomen of crustaceans.

**Symbio'sis** (Gr. *symbiosis*, a living together): a condition in which two organisms of different kinds live together in a mutually beneficial partnership.

## T

**Tac'tile corpuscle** (Lat. *tangere,* to touch): sense organ of touch.

**Tar'sus** (Gr. *tarsos,* sole of foot): the ankle-bones, also the last region of the leg of an insect.

**Taste bud**: end organ of taste found on the tongue.

**Teeth**: limy structures in the mouth of man and other animals, consisting of incisors or cutting teeth; canines, tearing teeth; and molars and premolars, crushing and grinding teeth.

**Ten'don** (Lat. *tendere*, to stretch): a band of connective tissue attaching muscle to muscle or muscle to bone.

**Ten'tacle** (Lat. *tentáculum*, a feeler): a flexible organ at the anterior end of an animal used for feeling, grasping, etc.

**Tes'ta**: the thick outer coat of a seed.

**Thal'lophytes** (Gr. *thallos,* young shoot; *phyton,* plant): plants having a thallus or ribbonlike body.

**Thorac'ic**: pertaining to the chest region.

**Tho'rax** (Gr. *thorax,* the chest): the part of the body between the head and the abdomen.

**Tissue** (Fr. *tissu,* a web): a collection of cells all more or less alike and having the same function.

**Tra'chea** (Lat. *trachia,* windpipe): the windpipe; also a respiratory tube of insects.

**Transpira'tion** (Lat. *trans,* through; *spirare,* to breathe): the giving off of water vapor from plants.

**Trichi'na**: pork worm, a parasitic roundworm causing the condition called trichinosis.

**Trimor'phic** (Gr. *tri,* three; *morphe,* form): flowers having three lengths of stamens and pistil; for example, the loosestrife.

**Tryp'anosomes** (Gr. *trypanon,* an auger): protozoa which cause diseases such as sleeping sickness.

**Tym'panum** (Gr. *tympanon,* a drum): the eardrum.

## U

**U'rea** (Lat. *urina,* urine): a nitrogenous waste excreted in the urine.

## V

**Vaccina'tion**: inoculation with a vaccine, containing living or dead bacteria, to protect the body from disease.

**Vac'uole** (Lat. *vacuus*, empty): a space in protoplasm containing air, water, sap, or food material.

**Varia'tion**: in biology, the occurrence of differences between individuals of the same species.

**Vein**: a tube which conveys blood to the heart.

**Ven'tral** (Lat. *venter*, belly): the opposite of dorsal.

**Ventila'tion** (Lat. *ventilare*, to air): changing of air in a room or building.

**Ven'tricle** (Lat. *ventriculus*, a little belly): a muscular chamber of the heart, which forces the blood out.

**Ver'miform appendix** (Lat. *vermis*, worm): a narrow tube about four inches long, closed at the outer end, near the beginning of the large intestine of man.

**Ver'tebræ** (Lat. *vertere*, to turn): bones of the vertebral column.

**Ver'tebrate**: an animal having a backbone.

**Vil'lus** (Lat. *villus*, shaggy hair): a minute projection, an absorbing organ of the small intestine.

**Vi'rus**: an unknown agent causing disease, as opposed to bacteria or protozoa which are known causes of specific diseases.

**Vi'tamin** (Lat. *vita*, life): unknown substances in food apparently necessary to support life.

**Vol'untary** (Lat. *voluntas*, will): subject to the will (used with reference to muscles), as opposed to involuntary.

## X

**Xe'rophyte** (Gr. *xeros*, dry): a plant which lives under conditions of extreme dryness.

**Xy'lem** (Gr. *xylon*, wood): the inner woody part of a fibrovascular bundle which conducts water up the stem

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